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ABSTRACT

This curriculum unit describes geothermal energy in the context of the world's energy needs. It addresses renewable and nonrenewable energy sources with an in-depth study of geothermal energy--its geology, its history, and its many uses. Included are integrated activities involving science, as well as math, social studies, and language arts. Higher-order thinking and problem-solving skills have been suggested or included in the activities whenever possible. This book is designed for use with grades 4-8 and contains lessons and activities that can be selected based on the class knowledge and ability and the time available. Each section contains Student Information and Student Activity pages. Also included is a For the Teacher section that contains tips, extra directions, and extra activities and demonstrations to enhance instruction. Sections include: Earth's Natural Heat, Using Earth's "Low" Temperature Heat, Generating Electricity: Using High Temperature Geothermal and Other Resources, and A Geothermal Scrapbook: Hot Items. Appendices contain a bibliography, a list of resources, and correlation with 1990 California Science Framework. (JRH)

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GEOTHERMAL ENERGY

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GEOTHERMAL ENERGY

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created by the

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TEACHER PREFACE

This curriculum unit describes geothermal energy in the context of the world's energy needs. It addresses renewable and nonrenewable energy sources with an in-depth study of geothermal energy – its geology, its history and its many uses. Included are integrated activities involving science, as well as math, social studies and language arts. Whenever possible, high order thinking and problem-solving skills have been suggested or included in the activities. The book is designed for use with grades 4 - 8: you choose which lessons and activities you would like to use, depending on the class knowledge and ability, and the time you have available. You duplicate only those pages you need for your students.

STUDENT INFORMATION

In each section you will find **Student Information** pages. Words in italics on these pages are listed in the Glossary. **Student Activity** pages are also provided along with the student information. These are all identified with a student symbol in the top corner. Duplicate the pages you want for your student packets; perhaps add other materials of your own.

STUDENT ACTIVITY

Following the student pages for each section , you'll find a **For the Teacher** section. Here there are some tips and extra directions to help you with the student activity worksheets. In addition, you'll find extra activities and demonstrations you can use to enhance your instruction. All of these are listed in order and labeled according to the subsection in the student background materials that they accompany. Enjoy!

Throughout this unit there are many activities requiring the use of heat. Please stress with your students the importance of the "Safety Precautions" discussed in the Student Preface.

The U.S. Department of Energy , the Oregon Department of Energy, the Geothermal Education Office , and any other parties associated with the development of this curriculum unit assume no responsibility for accidents or injuries which result from performing any of the activities suggested in this book.

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STUDENT PREFACE

Meet G. Arthur Mole, a retired professor who knows a lot about geothermal energy. Professor Mole will pop up from time to time throughout this curriculum as you learn about geothermal energy.

AN IMPORTANT MESSAGE FROM PROFESSOR MOLE:

Throughout this unit, you will find some interesting science activities to do. Be sure to read the following safety precautions before performing any of these activities.

SAFETY PRECAUTIONS

Safety and caution are very important when performing science experiments. Most science experiment accidents result from carelessness and impatience. Be sure to review and always use the following safety tips before doing any science laboratory-type experiment, no matter how simple it may seem.

1. Always work with or near other people. Never work alone. Make sure that your teacher or other responsible adult is close at hand. ALWAYS REPORT ACCIDENTS OR HAZARDS TO YOUR TEACHER (OR OTHER ADULT) AT ONCE.

2. Read and understand the directions before you begin. Be sure to study and follow any safety precautions that are included in the directions.

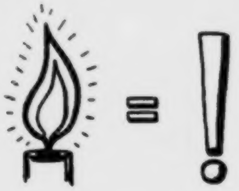
3. Long hair should be tied back and long sleeves rolled up. If aprons are available, wear them.

4. If safety goggles are available, wear them when performing activities involving heat especially when heating chemicals or oil. Use tongs and/or oven mitts as recommended.

5. Handle glassware with care. Once heated, glassware remains hot for a longer time than you might anticipate. Always get adult help if glass breaks.

6. Point test tubes away from yourself and others.

7. Use extra caution when working around flames and hot liquids. Be particularly careful around heated oil. Know the location of safety equipment (such as a fire extinguisher).
If a fire starts, DO NOT RUN and DO NOT PANIC. Always immediately get adult help. A small fire can often be extinguished with baking soda or sand. If a fire blanket is available, cover the fire with it, or douse the fire with a fire extinguisher.



8. Do not taste any materials you are using. Notify your teacher (or other adult) if you spill any chemicals.

9. Clean and return all materials to their proper places after each activity. Clean your work area carefully. Do not throw harmful chemicals, soil, or sand in the sink.

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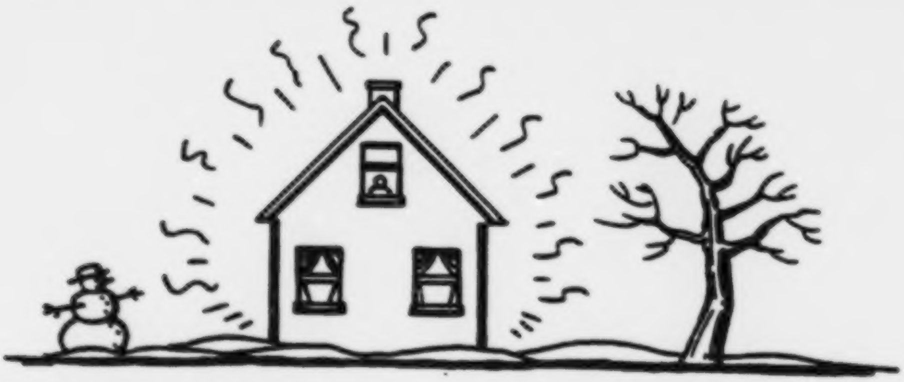
INTRODUCTION

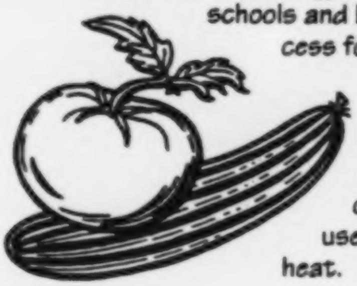
SECTION I

"Geo" means earth and "thermal" means heat. Therefore, geothermal means "earth heat." The heat from the Earth is continuously being regenerated deep inside our planet.

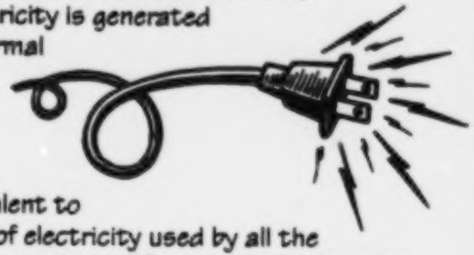
WHY IS GEOTHERMAL ENERGY IMPORTANT?



Geothermal resources are an important source of energy for both the United States and the world. Around the globe, people living close to Earth's natural hot spots make "direct use" of geothermal energy to heat homes, schools and businesses, to process food, grow plants, to raise fish and even alligators! In the U.S., the western states are the country's leading users of geothermal heat.



Some geothermal heat can also be used to make electricity. In the United States alone, enough electricity is generated from geothermal energy to supply over 3 million households. That's equivalent to the amount of electricity used by all the families in the states of Oregon and Washington combined!

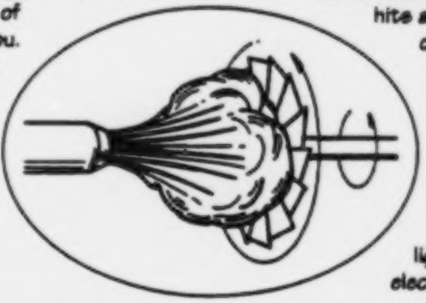


In this unit you will be learning about where geothermal energy comes from, the many ways we can use it, and why it is such an important energy source.

WHAT IS ENERGY?

Energy is the capacity to do work. It is the ability to move something, to heat it up, or change it in some way. Energy can be found in a number of forms, some of which are familiar to you. These include *mechanical energy, heat (thermal) energy, and electrical energy.*

You probably have or know about toys that can change from one form to another, called transformers. Well, energy can also transform from one form to another.



This is called *energy conversion*. An example of energy conversion is what happens when forceful steam hits and turns the blades of a machine called a turbine, which is used in the production of electricity. In this case, the forms of energy that are being converted are: heat energy (used to make steam from water) to mechanical energy (the moving turbine blades) to electrical energy (used to power machines, lights, heaters, appliances, and electronic equipment).

WHAT ARE ENERGY RESOURCES?

Geothermal heat is an energy resource. Other examples of energy resources are fossil fuels, nuclear fuel, moving water, the wind, and the sun. Energy resources help us do work. Our lives would be a lot different without them.

When we talk about energy resources, we call them either.....

NONRENEWABLE *OR* RENEWABLE

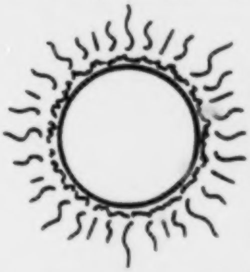
Nonrenewable *energy resources* are resources that get used up before more can be made. Nature has been providing us with some resources for *fuel* which take hundreds of thousands and even sometimes millions of years to make. These include fossil fuels (coal, oil, natural gas) and some minerals (such as uranium). Even though the earth is always creating more of these, it will be a LONG wait - maybe millions of years - before more are available. Therefore fossil fuels and uranium are considered nonrenewable because they aren't replaced within a reasonable amount of time.

USING FOSSIL FUELS

The most widely used nonrenewable resource group, fossil fuels, must be burned in order to be useful. This burning is called *combustion*. Combustion usually creates heat energy which assists us in heating our homes, for cooking and for bathing. Heat is also useful for making steam to produce electricity.

One result of burning fossil fuels is air pollution. Compounds such as carbon dioxide, nitrous oxide, and sulfur dioxide are produced during combustion. These compounds may contribute to environmental problems.

Renewable *energy resources* are resources that can be used over and over again without being used up. This is because nature is always replacing them. Examples of renewable resources are the sun, earth's heat, wind, wood and water.



Outside the surface of the planet, a constant supply of wind and water is available for use as energy. The sun's rays themselves can be used directly for electrical energy and heat. And deep inside the planet natural forces are constantly creating more heat - so, in a way, we are riding around on a giant heat engine, full of energy available to do work for us.

USING RENEWABLE RESOURCES

One of the best things about many renewable resources is that most of them – like geothermal – don't rely on burning, so there is very little pollution. Today, people concerned about our environment look to renewable resources as the least polluting energy sources. People are also concerned about "using up" the earth's resources, because these resources will also be needed by future generations. This is why many people today encourage the use of renewable resources. With proper management, renewable resources can be sustained for humankind indefinitely.

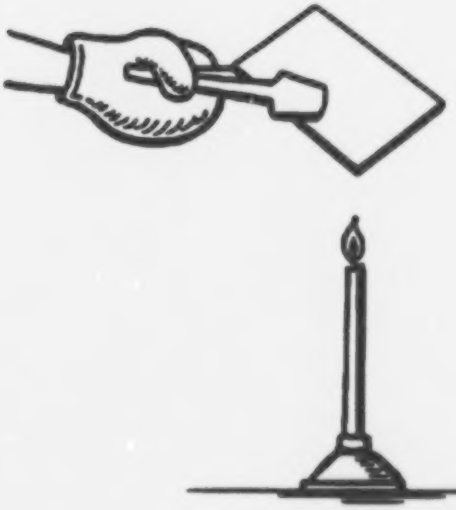
STUDENT ACTIVITY

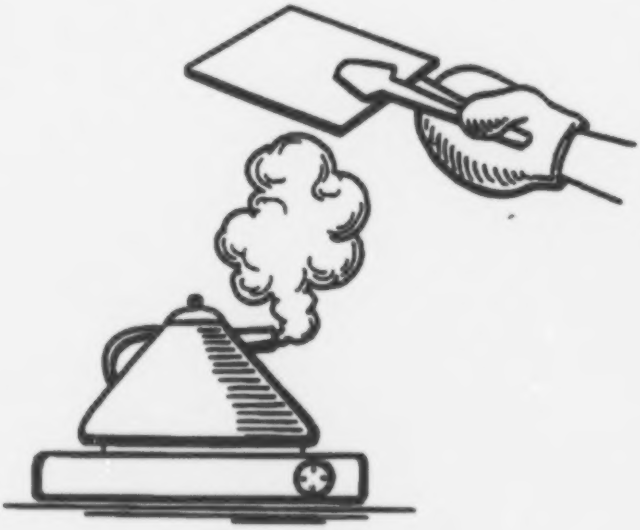
DO IT WITH MIRRORS: A DEMONSTRATION OF THE EFFECTS OF BURNING FUELS

Remember that when we burn something, a chemical reaction called "combustion" happens. As a result of this reaction some new materials are created which usually go into the air. Soot, for example, is a byproduct of combustion. Combustion of fuel is one of the main causes of air pollution.

We burn fuels to get them to do work for us, such as making engines run in cars. We also burn fuels to heat water to make steam. The steam, as you will learn later, is used to help generate electricity. In certain places we can use steam directly from the earth – geothermal steam – to make electricity (see Section IV).

In this demonstration you will 1.) see the results of combustion and 2.) compare the use of combustion to the use of a clean energy source such as geothermal steam.





Materials:

- candle
- candle holder
- matches or lighter
- small mirror
- kitchen tongs
- hot mitt
- tea kettle
- heat source such as a hot plate
- a source for cleaning the mirror such as soap
- water and towels
- goggles, if possible

Directions:

1.) With adult supervision, light the candle (standing in its holder).

2.) Wearing the mitt, hold the mirror in the flame using the kitchen tongs. Do this for about 5 seconds or so.

3.) Take the mirror away and look at the results. Be ready to describe what you see and where you think it came from.

4.) Now try a different version of the experiment . First wash and dry the mirror well.

5.) Get the tea kettle actively boiling with water.

6.) Wearing the hot mitt, use the kitchen tongs to hold the mirror over the steam coming from the tea kettle. Don't hold it too long – just a few seconds – or the mirror might slip due to the moisture.

7.) Look at the mirror to see the result of using hot water as your energy source. Be ready to discuss the results of both demonstrations and how they relate to energy and pollution.

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ENERGY CONSERVATION

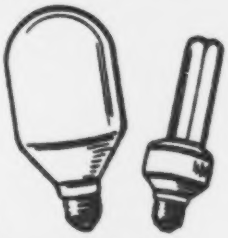
No matter what energy resources we use (renewable or not), we need to pay close attention to how we use them. When we manage our resources with care, then we are practicing energy conservation – a way of life that benefits our country and all the earth.

R-30
INSULATION

At present, we are still very dependent on fossil fuels for most of our energy needs. Because over half of the fossil fuel we use comes from other countries, we are dependent on those countries for some of our energy. Conserving fossil fuels means we have to import less and so are not as dependent on other countries. And, when we reduce our use of fossil fuel, we produce less pollution at the same time, which protects our environment. For example, alternative fuel cars, such as electric cars – which don't burn fossil fuels – are one way to cut down on air pollution.

We can all take responsible steps to reduce the amount of energy we use – and this does not mean having a cold house or school. We can add insulation and weather stripping to our homes and other buildings, turn off unneeded lights and turn down the heater when we really don't need it or are not home. We can use sources such as geothermal or solar energy, for heating and making electricity.

Another way to practice conservation is to use machines, appliances, and cars that use less electricity or fuel. These devices do their jobs without wasting a lot of energy, and therefore use less energy in the process. So energy conservation also means using energy efficiently.



Energy-Saving Compact Fluorescent Light Bulbs

Over time, some people have recognized the wisdom of using renewable resources such as earth's heat carefully and imaginatively. On the following page, you'll read about some of the creative uses of earth's heat - geothermal energy - that have been practiced over the years.

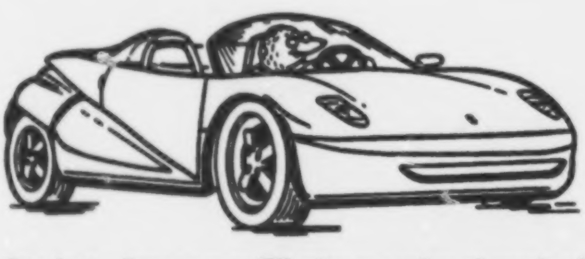
COGENERATION: "TWO FOR THE PRICE OF ONE"

Some manufacturing and power plants use a special system called cogeneration that is a great way to save energy. In many of these plants, a lot of heat or steam is often given off as "waste" in the process of making electricity, or refining oil or oil products. Instead of just "blowing off" the heat or steam, this energy is captured for another use. For example, in some places where oil is made easier to use (called oil refineries), waste heat from the oil refining process is used to turn turbines that generate electricity. In Oregon, some forest products mills also use their waste heat for electricity generation. Another method is found in Hawaii, where some sugar companies burn shredded, processed sugar cane to produce steam for their electricity generators. The steam that has gone through the turbine still has enough energy to process the sugar. Talk about energy efficient!

FORMULA FOR A CLEANER ENVIRONMENT

– Decrease Fossil Fuel Use
+ Increase Renewable Energy Use
– Decrease Energy Use (Conserve)

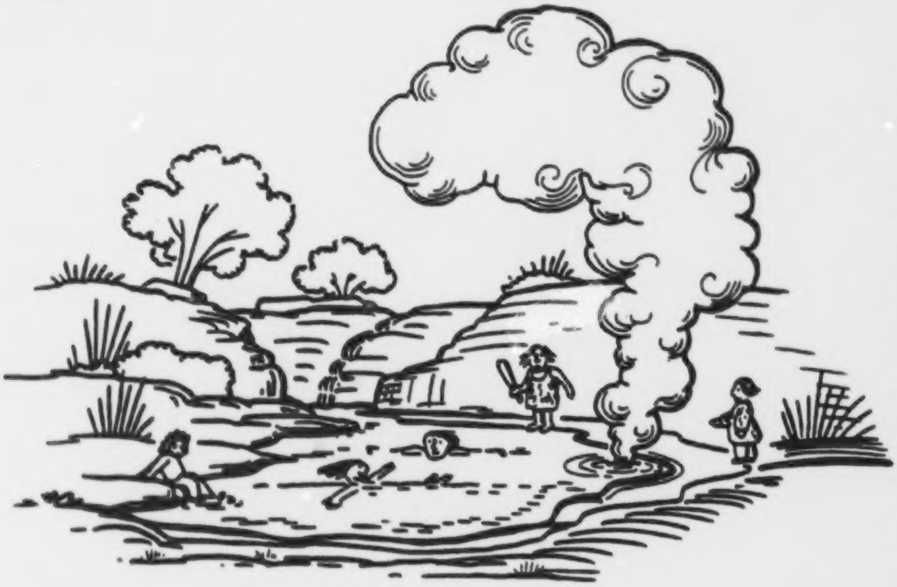
= A Safer, Cleaner Sustainable Energy Future



This Australian car gets 135 miles per gallon of gasoline!

STUDENT INFORMATION

GEOTHERMAL THROUGH THE AGES

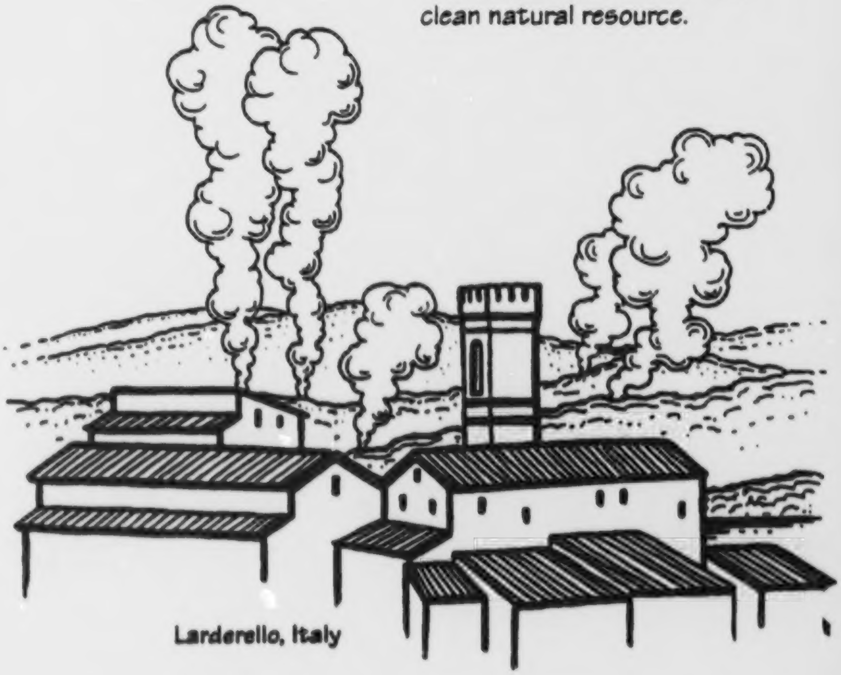


Since the beginning of the earth, geothermal resources have been generating inside our globe. Humans have been "tapping" into geothermal resources for thousands of years. Some scientists think that Stone Age people must have used geothermal heat. There is evidence in Europe that as early as 3,500 years ago, the Etruscans bathed in geothermal hot springs. The Romans swam in geothermally heated pools, treated eye and skin disease with the waters from mineral hot springs, and heated buildings in Pompeii with geothermal waters. During the Middle Ages people even fought over who would get to use the land on which hot springs were located. In France certain towns began heating their homes using hot geothermal water. Before Columbus sailed to the Americas, the Maoris of New Zealand were cooking their food using geothermal resources.

In the 1800's and 1900's, the many uses of geothermal energy increased. In the late 1800's production of boric acid, an antiseptic still used today, and borax, a cleansing and water softening agent, began in Italy. These were made from byproducts of geothermal hot springs.

The first time geothermal steam generated electricity was in Larderello, Italy, in 1904. By 1913, electricity was being sold to the nearby community, and by 1943 there was enough electricity being produced from geothermal energy to power about 132,000 households. Tragically, all the Italian power plants were destroyed in World War II. But the geothermal reservoir was not damaged, and today this same geothermal area again produces lots of clean electricity.

Geothermal energy is used all over the world. It brings heat and helps generate electricity for those of us who are lucky enough to be able to benefit from this renewable, reliable, clean natural resource.



Larderello, Italy

HOW DOES IT COMPARE?

Metric and Customary Measurements

As you've learned, geothermal energy is used all over the world. When talking about and using geothermal energy, scientists and other people in the geothermal industry need some common languages when they refer to measuring amounts of energy and quantities of resources. As students of energy resources, we need to also understand these measurement languages, or systems.

The two most widely used measurement systems are *Customary Measures* and the *Metric System.*

In the United States, we measure things using Customary Measures. However, in many places around the world people use the Metric System. Once you get the hang of it, the Metric System is much easier and more precise to use.

Scientists everywhere use the Metric system. For example, when measuring temperature, people in the United States usually use the *Fahrenheit System*. However, scientists in the United States use *Celsius temperatures,* which are based on the Metric System. So, it's a good thing to know about the Metric System and how to change things from Customary to Metric and back again.

Here are some things to know about the Metric System:

Some Basic Metric Units:

length:	**meter** (millimeter, centimeter, kilometer)
volume:	**liter/cubic meter** (milliliter, cubic centimeter)
mass/weight:	**gram** (milligram, centigram)
temperature:	**degrees Celsius**
area:	**square meter** (square kilometer)

The metric system is based on tens:
The prefixes tell you what fraction or multiple of the unit you are using. Here are some of them:

kilo	**1000 times**
centi	**1/100 of (0.1)**
milli	**1/1000 of (.001)**

For example, one kilometer is 1000 meters. There are 1000 meters in one kilometer. A millimeter is 1/1000 of a meter. That is, there are 1000 millimeters in a meter.

For your reference:
1 meter is a little less than a yard.
1 kilogram is a little more than 2 pounds.
1 kilometer is less than a mile.

Some common temperatures:

		Fahrenheit	**Celsius**
boiling		212°	100°
body temperature		98.6°	37°
warm day		86°	30°
room temperature		68°	20°
freezing		32°	0°

Metric and Customary Measurements Continued

Here are some formulas to help you convert back and forth with Metric and Customary:

Inches to Centimeters: Multiply inches times 2.54
Centimeters to Inches: Multiply centimeters by 0.394

Feet to Meters: Multiply feet by 0.305
Meters to Feet: Multiply meters by 3.281

Square Feet to Square Meters: Multiply sq. feet by 0.305
Square Meters to Square Feet: Multiply sq. meters by 10.764

Miles to Kilometers: Multiply miles by 1.61
Kilometers to Miles: Multiply kilometers by 0.621

Quarts to Liters: Multiply quarts by 0.946
Liters to Quarts: Multiply by 1.057

Ounces to Grams: Multiply by 28.35
Grams to Ounces: Multiply by 0.035
Pounds to Grams: Multiply by 453.592
Pounds to Kilograms: Multiply by 0.454
Kilograms to Pounds: Multiply by 2.205

Cubic Yards to Cubic Meters: Multiply cubic yards by 0.765

Fahrenheit to Celsius: Subtract 32 from Fahrenheit temperature, multiply the difference by 5, then divide the product by 9. $[F = (C)(9/5) + 32]$

Celsius to Fahrenheit: Multiply Celsius temperature by 1.8, then add 32 $[9/5C+32$ or $1.8C+32]$

HOW DOES IT COMPARE?

Using Formulas to Convert Metric and Customary Measurements

1. For this problem you will need:

- two thermometers: 1 Celsius, 1 Fahrenheit or one thermometer that will give a Celsius and a Fahrenheit temperature reading with masking tape over the Celsius side so you can't read it
- containers of water of different temperatures ranging from icy cold to hot
    a. Estimate, then find, the Fahrenheit reading of various temperatures of water: icy cold, cool, warm, hot. Record the temperatures.
    b. Convert the Fahrenheit temperatures to Celsius.
    c. Check your Celsius conversions by using your thermometer to find the Celsius temperatures of the various waters you tested.

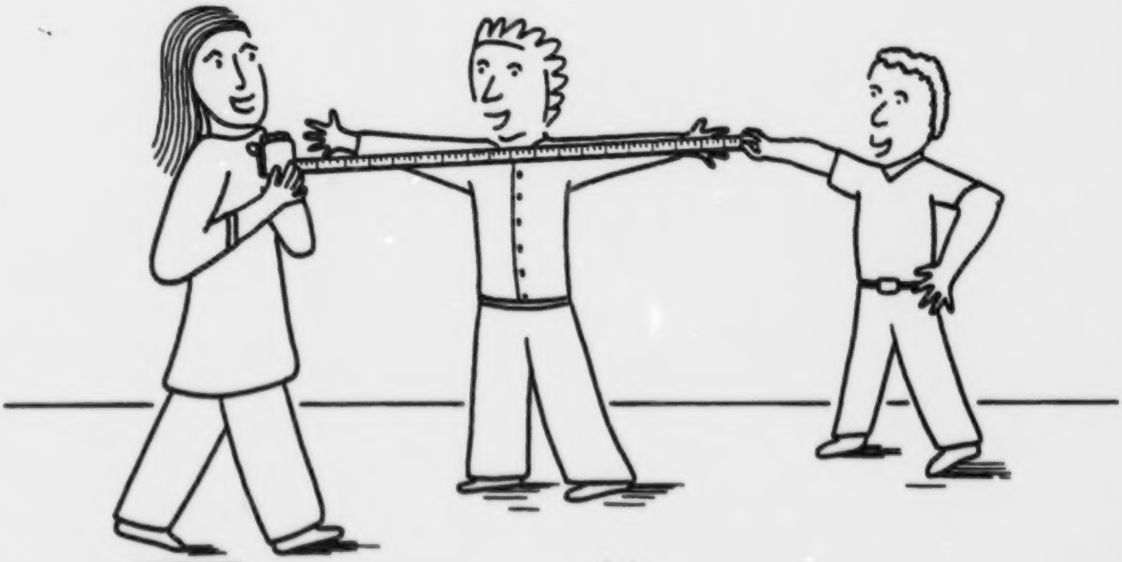
2. Magma is hot molten or partially molten rock the temperature of which can exceed 1000° Fahrenheit! Convert this temperature to Celsius.

3. Geothermal reservoirs are found from 200 to 14,000 feet below the earth's surface. What would these depths be using the Metric system? Would you convert to meters or kilometers?

4. Sam's geothermally-heated greenhouse is 60 cubic yards in size. Convert this to Metric units.

5. One of the most famous areas in the U.S. where there are geothermal power plants is The Geysers, located near Santa Rosa, California. Using an atlas, find the approximate distance in miles from Santa Rosa, CA, to your home town. Convert this distance to kilometers.

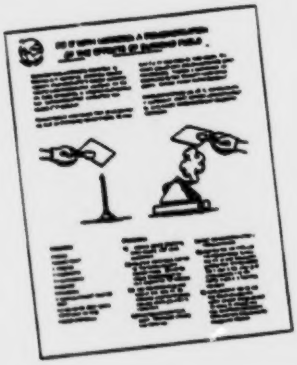
6. Bonus: Using a measuring tape (or string and a measuring stick), measure a partner. Measure things like height, circumference around the head, the length of an arm from shoulder to middle fingertip, and so forth. Decide before you begin whether you will use Customary or Metric measurements. Record all your findings. Switch partners and measure again. Then convert all your findings to the other measurement system. Check your answers if you can by measuring.



FOR THE TEACHER

1.) **Show Videotape,** "Geothermal Energy - A Down to Earth Adventure," featuring G. Arthur Mole. Professor Mole is the mascot of this unit and in the video gives an excellent overview of the concepts covered in more depth in this unit. (Videotape available from Geothermal Education Office. See Resources, Section VII)

2.) **Science Activity: Do It with Mirrors: A Demonstration of the Effects of Burning Fuels"** (Student Worksheet Provided)



Materials: (per student group)
- candle
- candle holder
- matches
- small mirror
- kitchen tongs
- hot mitt
- tea kettle
- heat source such as a hot plate
- a source for cleaning the mirror such as soap
- water
- towels

Directions: Found on Student Worksheet.

Management Suggestions: You may want to use this activity as a teacher demonstration or divide your class into groups for more hands-on experience. Remember to warn students about working around open flames and steam. Have plenty of hot mitts available, have long hair pulled back, and sleeves rolled up. Remind students to use these safety techniques for any science activity using heat or chemicals.

3.) **Social Studies Activity:** Ask students to list as many current uses and locations of renewable energy sources as they can. Answers can range from small devices such as solar-powered calculators to large scale production of electricity from hydroelectric dams to occasional uses like wood for cooking on camping trips and wind for sailboats.

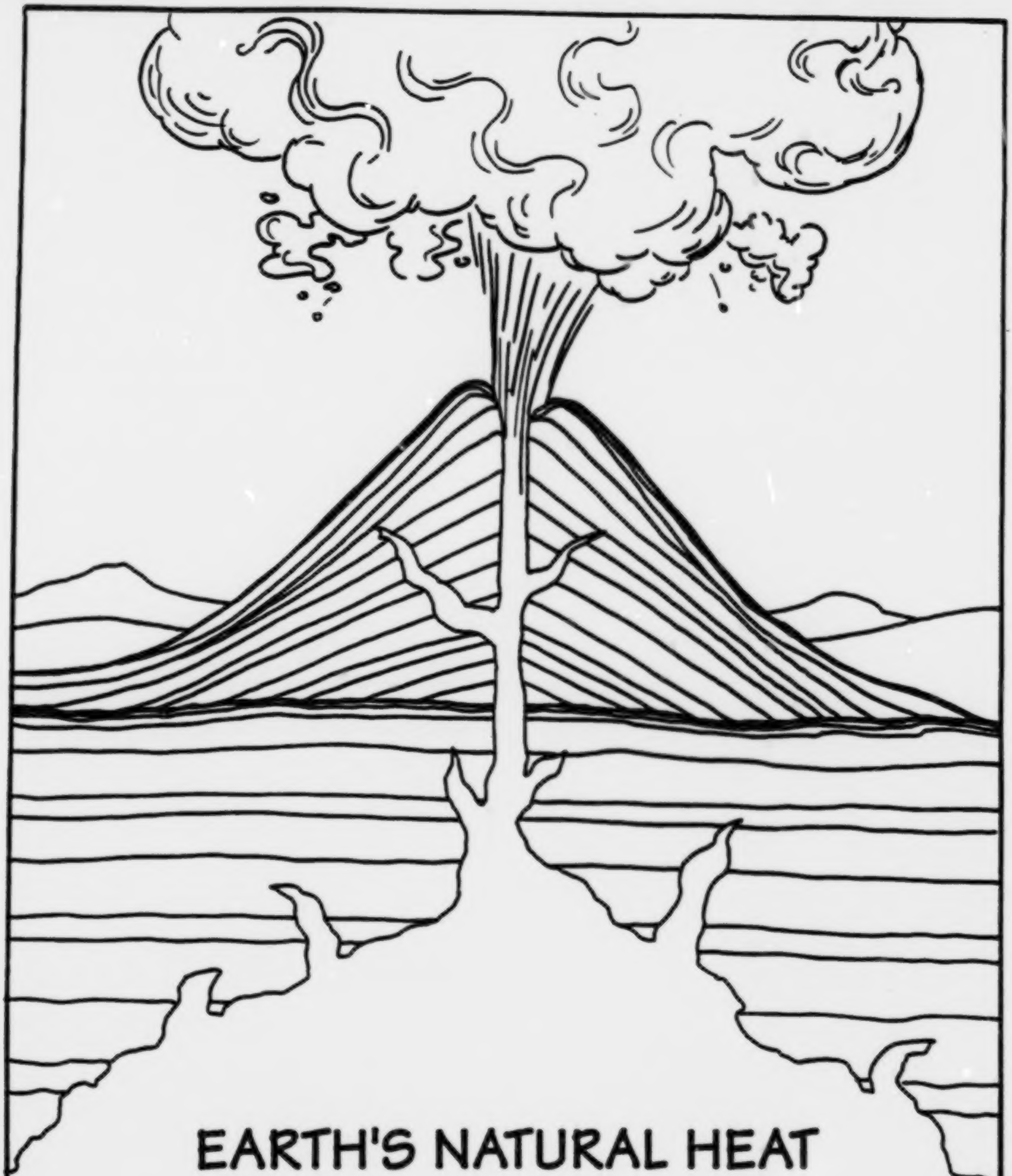
4.) **Language Arts/ Art Activity:** (follow-up to Activity 3.) Tell the class to take a mental trip into the future. It is 50 years from now. Half of all the energy we use in the United States comes from renewables - wind, sun, water (hydro power), biomass, earth heat (geothermal). Ask students to think of some inventions that have made this possible. How are houses, offices, and schools heated and lighted? Where does the energy used to run factories come from? What do people use for transportation? Have students write down their ideas or draw pictures. Collect these pictures and ideas. At the end of the unit, review with them what they did and have them revise their ideas.

5.) **Social Studies/Geography / Current Events Activity:** Locate a world map which you won't mind getting marked up and post it in the classroom. If you're going to have an "Energy", "Geology", or "Geothermal Energy" bulletin board, this would be a great place to put the map. Ask your students to keep on eye on the newspaper and other sources such as magazines for anything about geothermal energy, volcanoes, earthquakes, geysers, and hot springs. Have them clip or copy the article to bring in to class. Have them locate where on the map their article's subject occurs. Have the students devise a method to mark the place on the map. Keep this as an ongoing activity for a good period of time - an entire quarter, semester or even longer. As marks are made on the map of all the geologic occurences, certain areas will stand out as being especially active. In Section II, students will read about the Ring of Fire. Later on, after the map is marked up, you may encourage students to compare their classroom map and the Ring of Fire.

6.) Other materials are available from the Geothermal Education Office and other sources. For example, a world map with highlights of geothermal activities occurring around the globe is available from the Geothermal Education Office. (See Resources, Appendix, Section VII)

7.) **Answers to: How Does It Compare?**

1. Answers will vary
2. 1000° F = 538° C
3. 200 feet = 61 meters
   14,000 feet = 4,270 meters
4. 60 cubic yards = 45.9 cubic meters
5. Answers will vary
6. Answers will vary



EARTH'S NATURAL HEAT

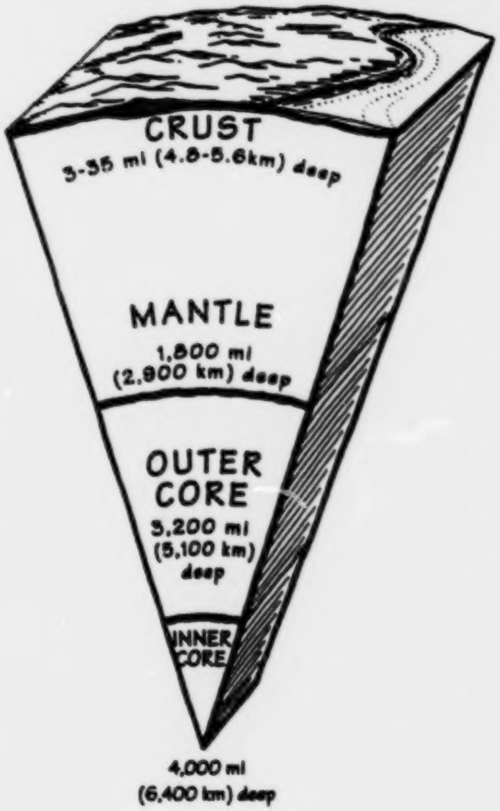
SECTION II

INSIDE THE EARTH

Though the earth seems very solid to us as we walk on it, it is actually always moving and changing. It's been doing so for over 4.5 billion years! The earth is also very hot inside, all the way to the center – about 4000 miles (6,400 kilometers) deep.

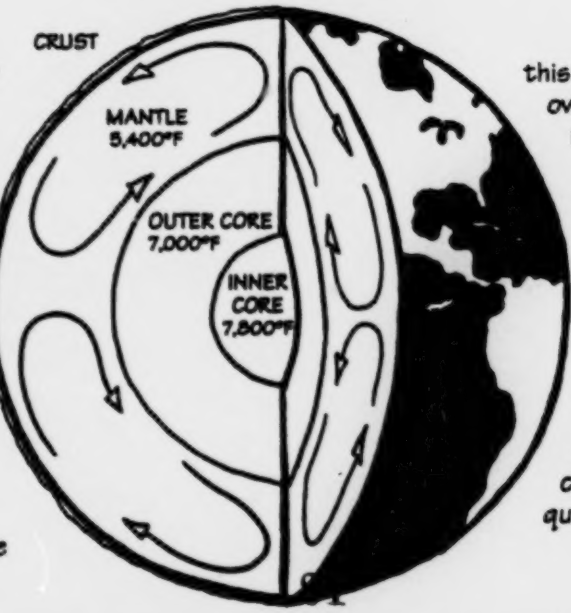
Compare the earth to a hard-boiled egg. The egg shell is like the *crust of the earth*. It is a layer of solid rock which is about 3 miles (4.8 kilometers) thick under the oceans and up to 35 miles (about 56 kilometers) thick under the land. Below the crust is the "white" of the egg, which is the part of the earth that is called the *mantle*. This is about 1,800 miles (2,900 kilometers) below the surface. Rock in the mantle is different from that of the crust and is very hot. Then there is the earth's center, which is a bit different from the yolk because it has two parts. The *outer core* is mostly melted iron and the *inner core* is mainly solid iron. Scientists think that the outer core is about 3,200 miles (5,100 kilometers) down from the earth's surface and that the inner core – which goes all the way to the center of the earth – is about 4,000 miles (6,400 kilometers) deep. The temperatures at the very center of the earth may reach up to 7,800° F (4,300°C)!

HOW DEEP ARE THE LAYERS OF THE EARTH?



MOVING MANTLE

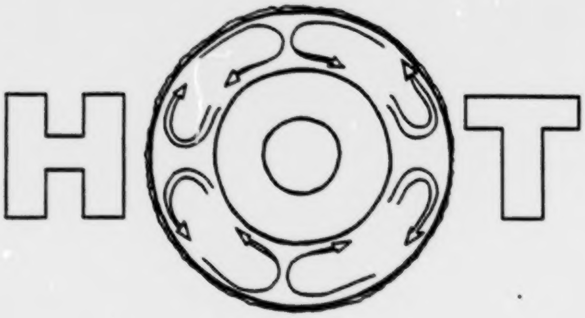
The mantle, the thick layer just beneath the earth's crust, is heated by the earth's hot core. Because it is so hot, mantle rock is flexible enough to flow very, very slowly. As the mantle rock is heated from below, it becomes lighter, or less *dense*. When this happens, it rises up towards the earth's surface. Nearer the surface, it cools and becomes heavier (or more dense), so it sinks. Because this action happens over and over, mantle rock is always moving. The pattern of movement of the mantle is something that happens to many materials when they're heated. These patterns are called *convection currents*. Sometimes, the results of this slow movement end up in some very fast surface changes such as earthquakes or volcanoes.

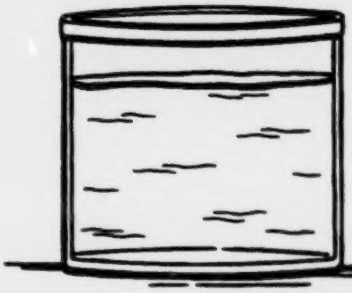


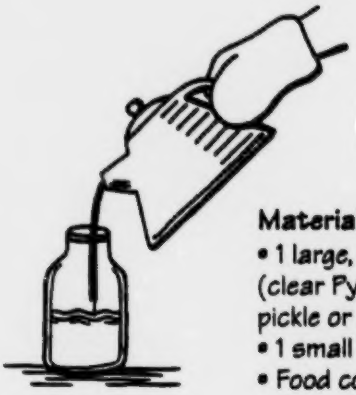
CONVECTION CURRENTS: MANTLE ON THE MOVE

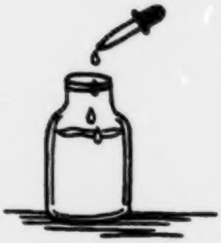
In this experiment you will use swirling colored water to show how hot flexible mantle rock moves in patterns called convection currents.

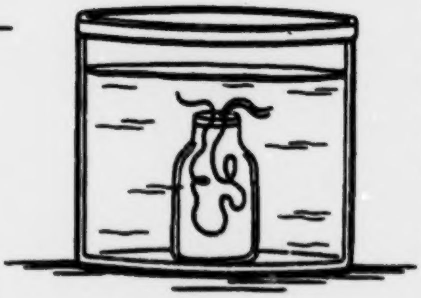
Remember that the mantle is slowly heated by the earth's core. When heated, mantle rock gets lighter (less dense), so it rises up towards the earth's surface. As it gets nearer the surface, it begins to cool. Thus it gets heavier (more dense) and so it sinks. This happens over and over again, keeping the mantle very slowly on the move.











Materials (Per group of students):
- 1 large, open-mouth straight-sided jar or bowl (clear Pyrex bowl or canning jar, such as a large pickle or spaghetti sauce jar)
- 1 small bottle that will fit in the large jar or bowl
- Food coloring or ink with dropper
- A way to heat water
- Water
- Goggles if possible
- Mitts
- Tongs

Directions:

1.) Fill the large jar or bowl with cold water. Leave a space near the top so the water won't overflow when you put the small jar in.

2.) Fill the small bottle full of boiling water. Add a few drops of the food coloring or ink.

3.) Using tongs and wearing mitt, lower the bottle into the jar or bowl very carefully. Make sure the cold water covers the small bottle. Watch to see what happens to the hot colored water.

4.) Be ready to describe what you observe and to explain why the hot, colored water moves the way it does.

FLOATING PLATES AND THE "RING OF FIRE"

Let's look more closely at the crust of the earth. Picture an egg shell cracked all over. The shell is like our earth's crust, which is actually cracked into huge pieces called *tectonic plates*. The convection currents in the mantle have caused these cracks in the crust. Because the plates float on the mantle, they are constantly being pushed about by the currents. Although we don't feel it, they are always in "slow motion". (They only move a few inches a year.) The movement of the tectonic plates is sometimes called *continental drift*. The general process is referred to as *plate tectonics*.

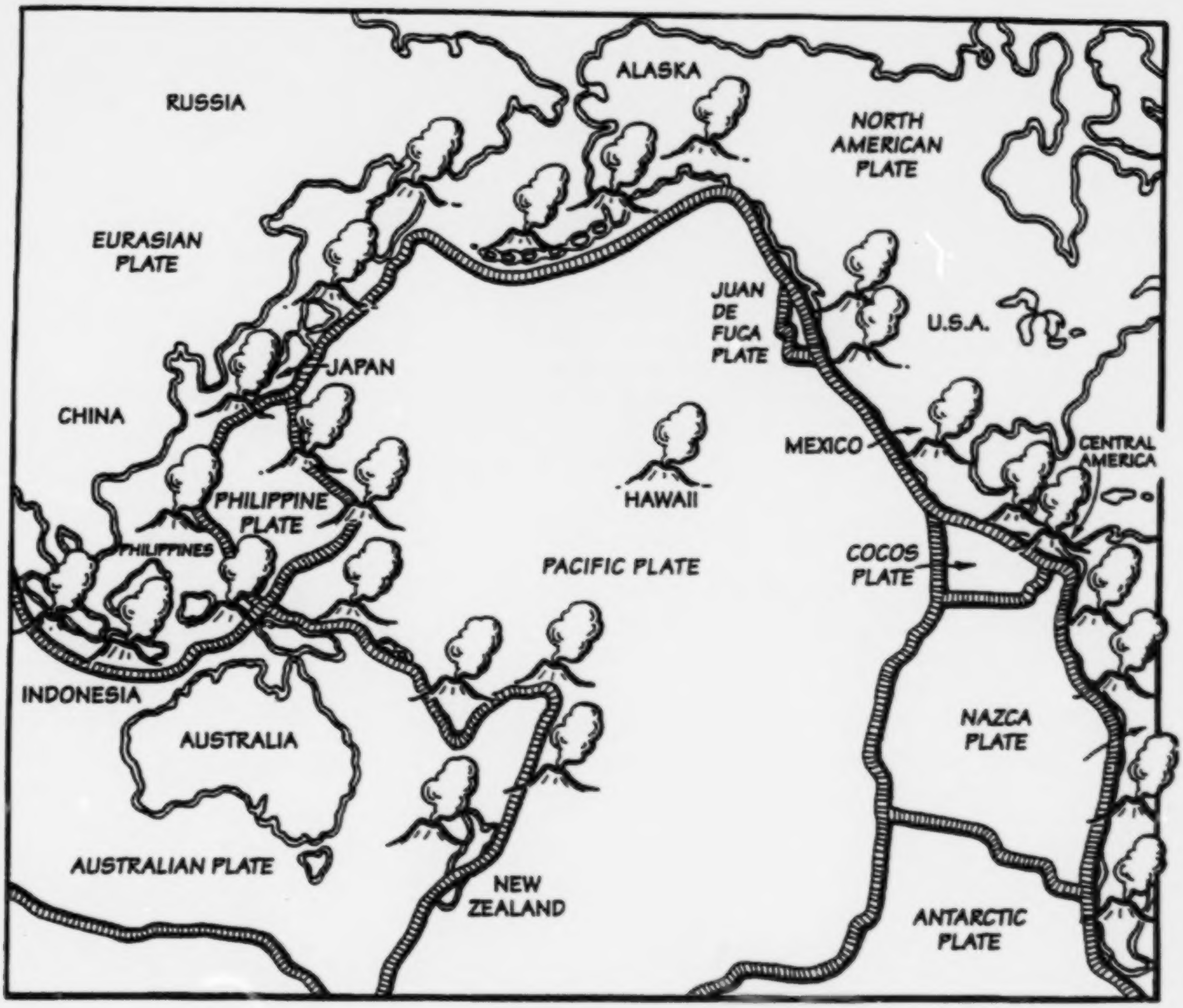
The western edge of the North American continent is an area where the Pacific oceanic plate is grinding along the North American continental plate (at a very slow rate). Those who live in this area know that this area has a number of potentially destructive volcanoes in the north and earthquakes in the south. At the same time, however, they are also fortunate enough to have easier access to Earth's heat.

Tectonic plate movement can result in action at the plate edges: the plates can push against each other, grind past each other, move away from each other, or one plate can slip beneath another. Moving plates often cause earthquakes and visible geothermal occurences such as *volcanoes, geysers, and hot springs.*

The edges of a number of the tectonic plates meet in an area surrounding the Pacific Ocean. The result is a belt of intense volcanic and geothermal activity called the Ring of Fire. The Ring of Fire is bordered by New Zealand, the Philippines, Japan, the Aleutian Islands, and the western edges of North, Central, and South America.

The Ring of Fire and other hot spots in the world are evidence of tectonic plate movement. Most of the world's accessible geothermal energy is concentrated in these areas.

THE RING OF FIRE


RUSSIA
ALASKA
NORTH AMERICAN PLATE
EURASIAN PLATE
JUAN DE FUCA PLATE
U.S.A.
JAPAN
CHINA
MEXICO
CENTRAL AMERICA
HAWAII
PHILIPPINE PLATE
PHILIPPINES
PACIFIC PLATE
COCOS PLATE
INDONESIA
AUSTRALIA
NAZCA PLATE
AUSTRALIAN PLATE
NEW ZEALAND
ANTARCTIC PLATE

Note: See related maps, pages 59 and 69.

FITTING IT TOGETHER: CONTINENTAL DRIFT

Remember we learned that geologists believe the continents are slowly moving around the earth's surface in a process called continental drift. Scientists also think that, millions of years ago, most of the continents as we know them today formed one big land mass. They call this huge super-continent *Pangaea*, meaning "all lands." The theory is that Pangaea slowly broke apart into the continental plates which then drifted around the Earth's surface to the positions we know today. If we take the main continents as they are today and move them back towards each other, we can see how they fit together.

Materials:

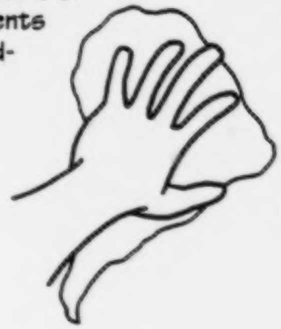
- Soft pencil
- Tracing paper
- Scissors
- Thick paper or cardboard
- Atlas

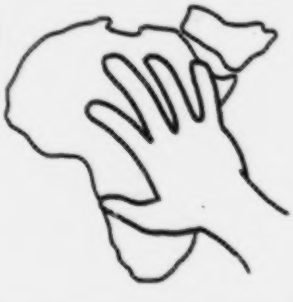
Directions:

Simplified Method:

1.) Find the shapes of Africa and South America in an atlas. Put your tracing paper over the shapes and trace around the edge of each continent.

2.) Now turn the tracing paper over and trace the same lines, using a soft pencil. You can then turn it back and draw over these soft pencil lines onto your heavy paper or cardboard. This should leave an outline of the continents on the cardboard.





3.) Cut out the shapes carefully. Place them the right way up and move the shape around until you can see how they could be fit together.

More Detailed Method:

1.) Use the above procedure, only do it for all of the main continental shapes. Make Europe and Asia into one big piece (called Eurasia), and include Greenland and Antarctica.

2.) Remember that the pieces won't all fit as neatly as Africa and South America.

3.) When you've fitted them together the best you can, ask your teacher to show you how scientists suggest the continents fit together long ago.

AN EXPERIMENT TO TRY

Crack an egg very gently and place in boiling water. The cooked egg white will push out and move the shell pieces. What does this remind you of?

CLUES FROM THE PAST

Even as recently as 20-30 years ago, people laughed at geologists who suggested that the continents may have all once been one big land mass. Scientists are now convinced that the continents were once joined together. One thing that made them look more closely at this idea was the fact that the ocean floors are spreading out from mid-ocean ridges, pushing apart land masses attached to them. Other evidence has been found to confirm this theory. For example, geologists have found the exact same pattern of layers of rock (called rock strata) in both Brazil and in Africa, just where the continents match when we fit them together in our "jigsaw puzzle". A fossil of a reptile called Lystrosaurus that lived 200 million years ago, has been found in Africa, India, China, and Antarctica. Other fossils of similar plants and animals have been found in South America, Africa, and Antarctica. All of this proves that once, millions of years ago, the continents were joined.

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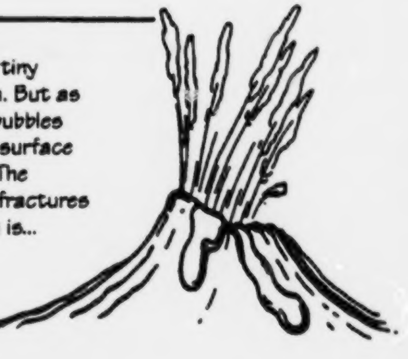
MIGHTY MAGMA

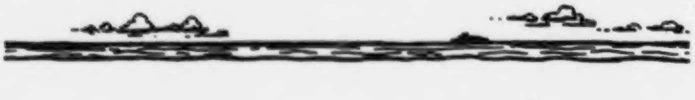
As you'll recall, the mantle is made of incredibly hot rock. There are even some places in the mantle where the rock actually melts.

This *molten* rock, a thick hot liquid, is called *magma*. Magma forms wherever temperatures and pressures are high enough to melt rock. These places include: areas where convection currents in the mantle bring heat close enough to melt rock, at the places where tectonic plates meet and separate, and in areas where one plate shoves underneath another one.

Because it is in melted form, magma spreads out, thus becoming lighter (less dense) than the surrounding rock; so it has a tendency to rise. Like steam rising through the cracks in a hot egg shell, streams of hot melted magma rise through the fractures (cracks) in the crust. Some of the magma reaches the surface, where it's called *lava*, often pouring out of, and sometimes forming, volcanoes. The magma that is still underground heats nearby rocks and water.

Magma, found in the mantle, is incredibly hot, up to 5,400°F (3,000°C). While still deep under the surface, the magma is under incredible *pressure*. Because of this pressure, gases such as *carbon dioxide* are kept dissolved in the liquid rock. As the magma rises towards the surface, the pressure starts to fall. When the pressure falls, some of the dissolved gas is released in the form of bubbles. First these are tiny because the pressure is still high. But as the pressure becomes less, the bubbles expand. The magma rises to the surface propelled by these gas bubbles. The magma and gas rise up through fractures in the crust and the result often is... a volcanic eruption !





Magma also comes out under the ocean from cracks in the sea floor. As the magma rolls out of these cracks it actually pushes the old sea floor out of the way. This causes the plates on either side of the crack to spread furthur apart. This action is called *sea-floor spreading* (and the areas where this occurs are called spreading centers). As the magma cools and hardens, it forms ridges. One huge example is the Mid-Atlantic Ridge. This is the spreading center that separates the North American plate from the Eurasian Plate and the South American Plate from the African Plate and is approximately 47,000 miles (75,000 kilometers) long!

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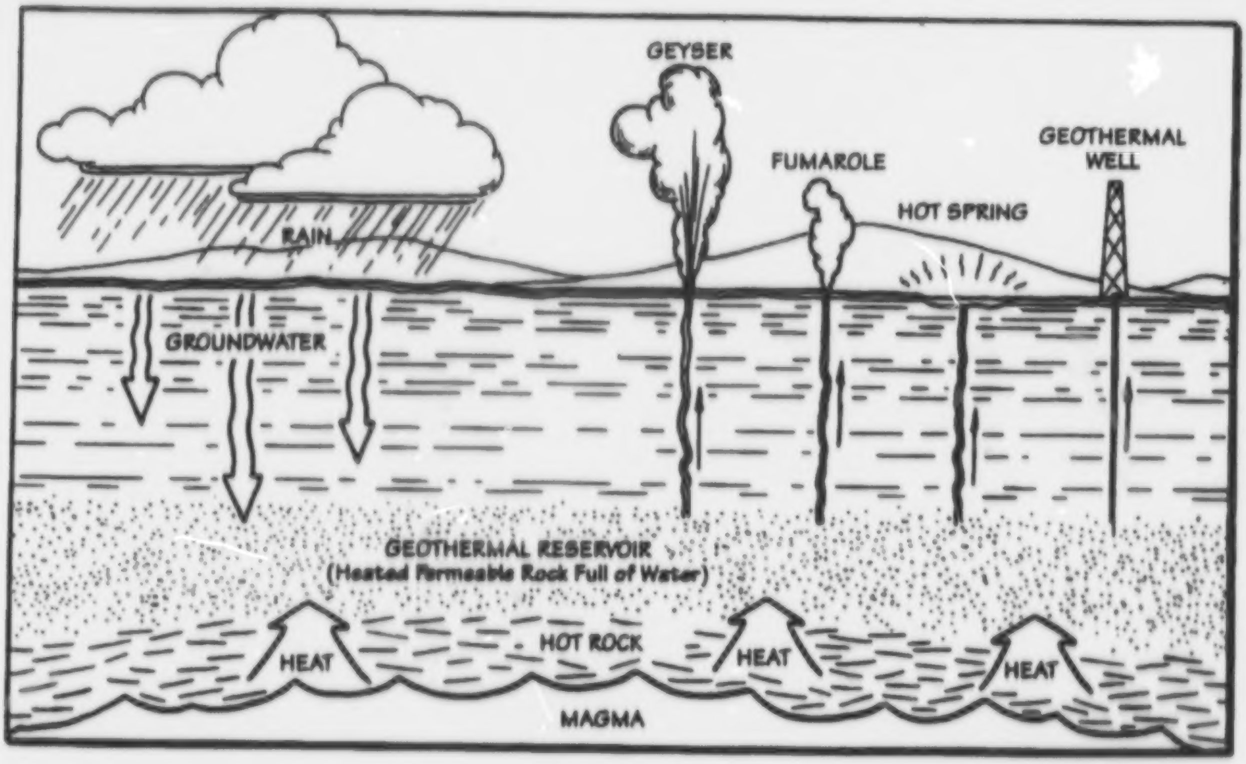
WATER DOWN BELOW



As magma rises closer to the earth's surface it heats up nearby rock. When this rock is close to water underground, it (and sometimes the magma itself) heats up this water.

Water is able to move underground—far below the surface—because some rock has tiny spaces, called pores. The more spaces certain rock has, the more porous it is. When there are connecting cracks (tiny fractures) between the pores, then rain and water from other sources can flow into and through the rock. This kind of rock is called *permeable*. (The rock that water can't pass through is called *impermeable*.) If a layer of permeable rock is surrounded by lots of impermeable rock, water gets trapped, collecting and forming a reservoir.

If this reservoir is near hot rock or magma, it heats up fast. If the hot water from this reservoir then finds cracks that allow it to flow to the surface, it may show up as a hot spring. If it spurts out like a fountain, it's a geyser. If it puffs out as steam, it's a *fumarole*. Sometimes, the hot water collects under the surface, trapped between layers of nonporous rock. Then it's called a *geothermal reservoir*.

TAPPING INTO GEOTHERMAL RESERVOIRS

We can put water and steam from surface hot springs to work right away. But what about all that hot water and steam in the geothermal reservoirs far below the surface? For these "hidden" geothermal resources to be useful, we need to bring them to the surface.

Geothermal engineers reach these resources by drilling wells down to the geothermal reservoirs far underground. Then, through pipes, the hot water and steam comes up to the surface.

Those who live in many areas near the Ring of Fire are fortunate because geothermal resources are more abundant and more accessible there, waiting to be "tapped" and used in many different ways.

WATER DOWN BELOW

STUDENT ACTIVITY

Groundwater is a very important part of the geothermal process. But how does rain end up under ground? Water seeps through sand, soil, and even rock through little air holes (pores). Rock that has these little air these holes is said to be porous.

If a material has spaces connecting the pores that allow water or other liquids to flow through, it is called permeable. Rain water collects in permeable rock, thus forming natural underground "reservoirs" of water. These water-rich areas can be found down to hundreds or even thousands of feet underground. If these reservoirs are close enough to hot rock or magma, then the water heats up and we have a geothermal reservoir.

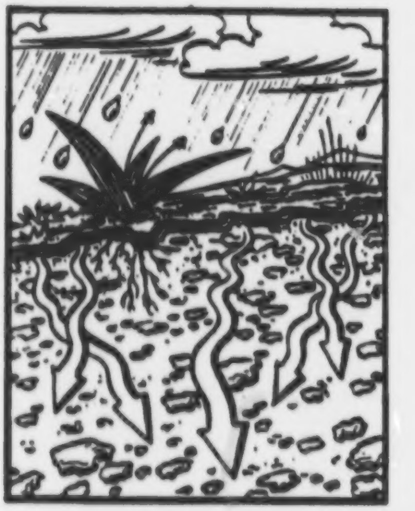
In this experiment you will test the "permeability" of various materials to see how easily water can seep through them.

Materials (Per group of students):

- Stuff to test (your teacher will tell you what you will be using—things like sand, soil, gravel, etc.)
- the top of a large, plastic drink bottle
- cheesecloth or muslin
- pouring pitcher
- measuring cup
- rubber band
- scissors
- watch or timer
- recording sheet or science notebook
- water
- paper cups to scoop up materials
- plastic spoons or other stirring tools
- containers to hold "used," wet stuff

Directions:

1.) Cut the top off the plastic bottle, as shown below. (Your teacher may have already done this for you.) Cut some cheesecloth or muslin and cover the top of the bottle, fastening the cloth on with the rubber band. Use several layers if you're using cheesecloth with big holes.

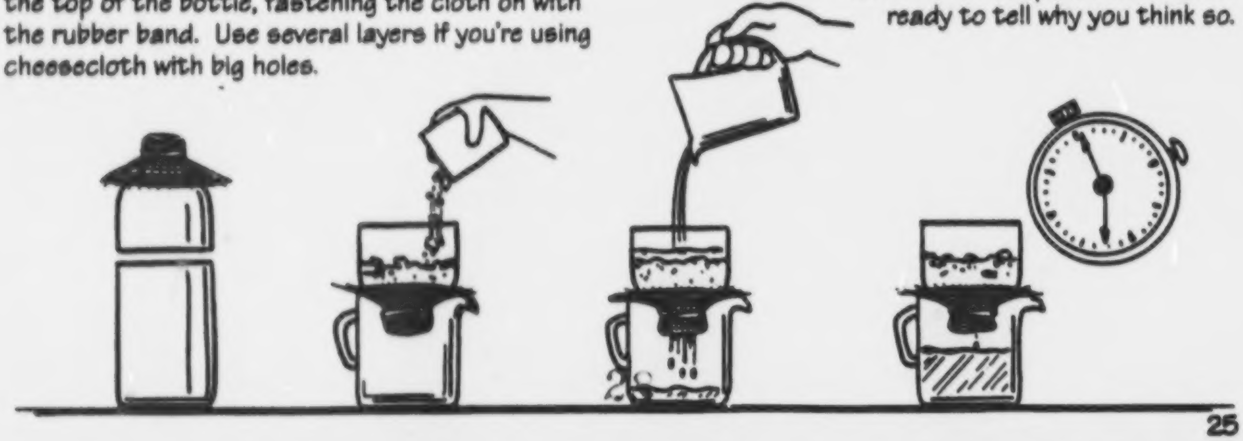


2.) Put the bottle "funnel" in the measuring cup. Fill the funnel with one of the materials to be tested. Mark the level it reaches on the outside of the "funnel."

3.) Measure an amount of water to pour through the test material and make a note of this amount. Fill the pitcher with the measured amount of water. Write down the time you start and pour the water into the funnel. Stir around in the narrow part of the funnel if the test material gets "stuck."

4.) Observe how long it takes the water to seep through the material and record how long it took. Now try another material, using the technique above. Be sure to always fill the material up to the same place you marked in Step 2.

5.) Draw conclusions about which materials seem to be the most permeable and be ready to tell why you think so.



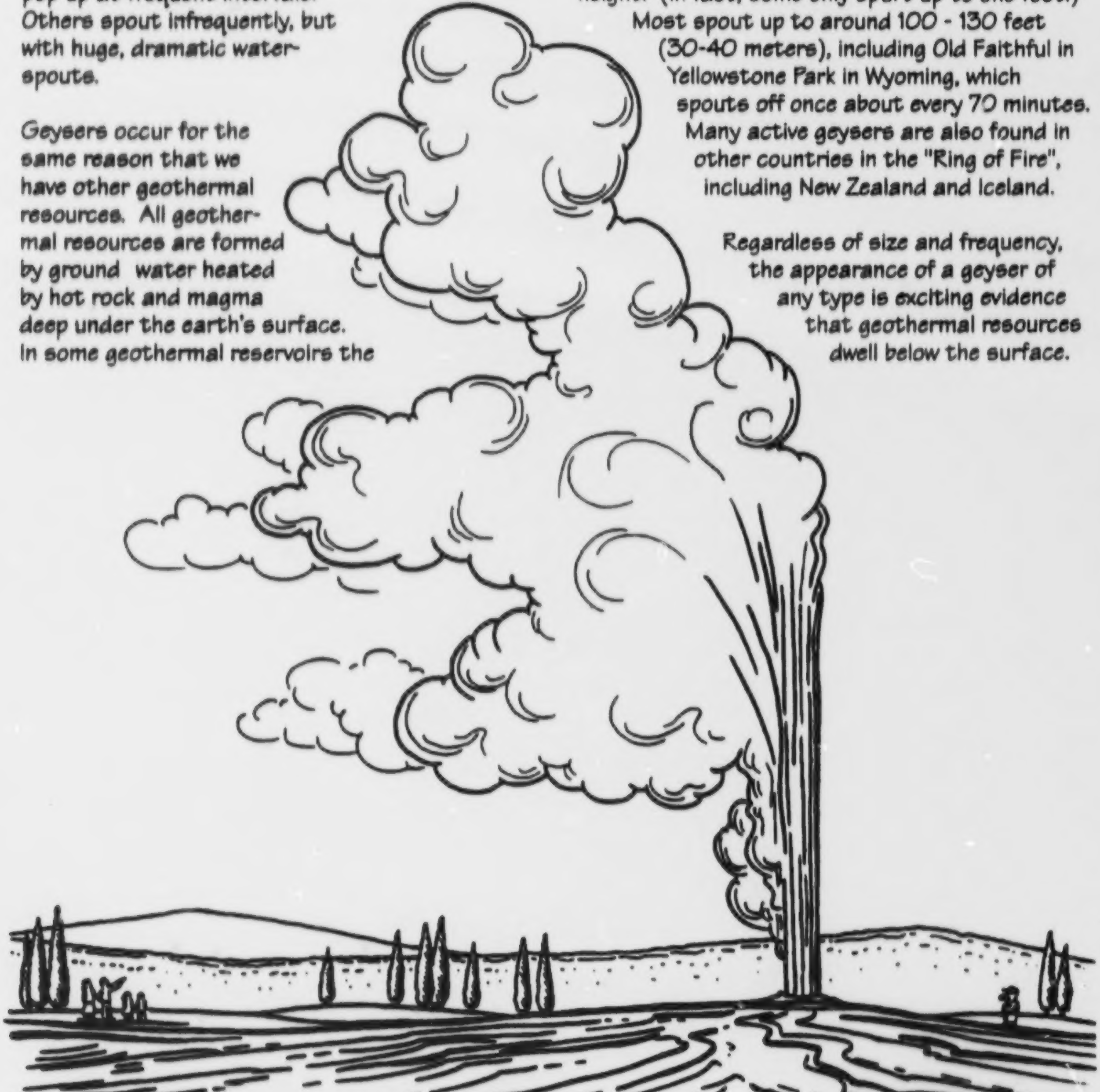
WHAT IS A GEYSER?

Scalding hot water and steam suddenly gush out of the earth. What is this strange apparition? It's a natural geothermal hot water fountain called a geyser. The name comes from the Icelandic word, "Geysir," meaning "gusher". Some geysers send up their spouts regularly, every few minutes, hours or days. Others are very irregular. Some geysers have small, bubbly spouts which pop up at frequent intervals. Others spout infrequently, but with huge, dramatic waterspouts.

Geysers occur for the same reason that we have other geothermal resources. All geothermal resources are formed by ground water heated by hot rock and magma deep under the earth's surface. In some geothermal reservoirs the pressure builds until it has to be released. So hot water and steam whoosh up through weak areas in the rock to the surface, making a hot water and steam fountain.

Some geysers have been known to shoot as high as 1,500 feet (460 meters), such as one found in New Zealand. Most geysers never reach this height. (In fact, some only spurt up to one foot!) Most spout up to around 100 - 130 feet (30-40 meters), including Old Faithful in Yellowstone Park in Wyoming, which spouts off once about every 70 minutes. Many active geysers are also found in other countries in the "Ring of Fire", including New Zealand and Iceland.

Regardless of size and frequency, the appearance of a geyser of any type is exciting evidence that geothermal resources dwell below the surface.



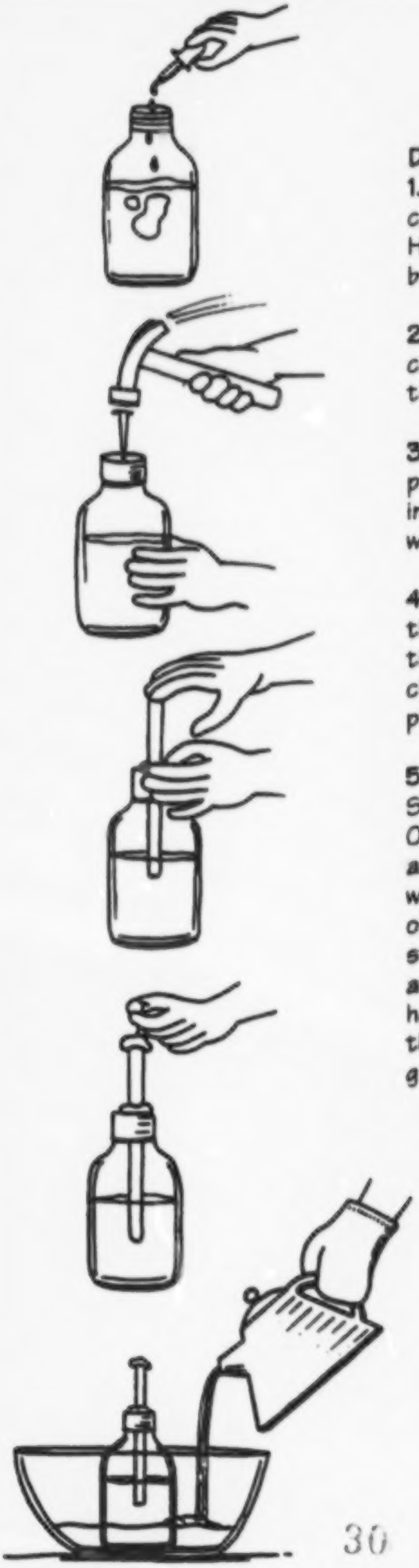
MAKE YOUR OWN GEYSER

In this experiment you will create your own "geyser" using some of the same forces that cause "real" geysers.

Geysers are the result of hot water and steam building up great pressure under the earth's surface. When the heat and pressure are great enough, the water expands (producing steam) and pushes the hot water in a gush up through weak spots and cracks in the earth's surface.

Materials
(Per group of students):

- bowl
- small strong bottle with a screw cap (preferably glass)
- modeling clay
- straw
- pin
- some food coloring or ink
- large nail & hammer
- a method to heat water
- hot mitts
- goggles, if possible
- water



Directions:

1.) Make a hole in the bottle's cap using the nail and hammer. Heat up water so that it will be boiling when you need it.

2.) Half fill the small bottle with cool water. Add a few drops of the ink or food coloring.

3.) Screw on the cap tightly and push the straw through the hole in the cap. Seal the hole well with clay.

4.) Stuff a small piece of clay in the top of the straw. Make a tiny hole all the way through the clay with the pin. Remove the pin.

5.) Pour hot water into the bowl. Stand the bottle in the bowl. Observe what happens. As the air inside the small bottle warms up, it will push the colored water up and out of the straw. This is because the air and water expand when they are heated and spread out, just as the steam expands underground.

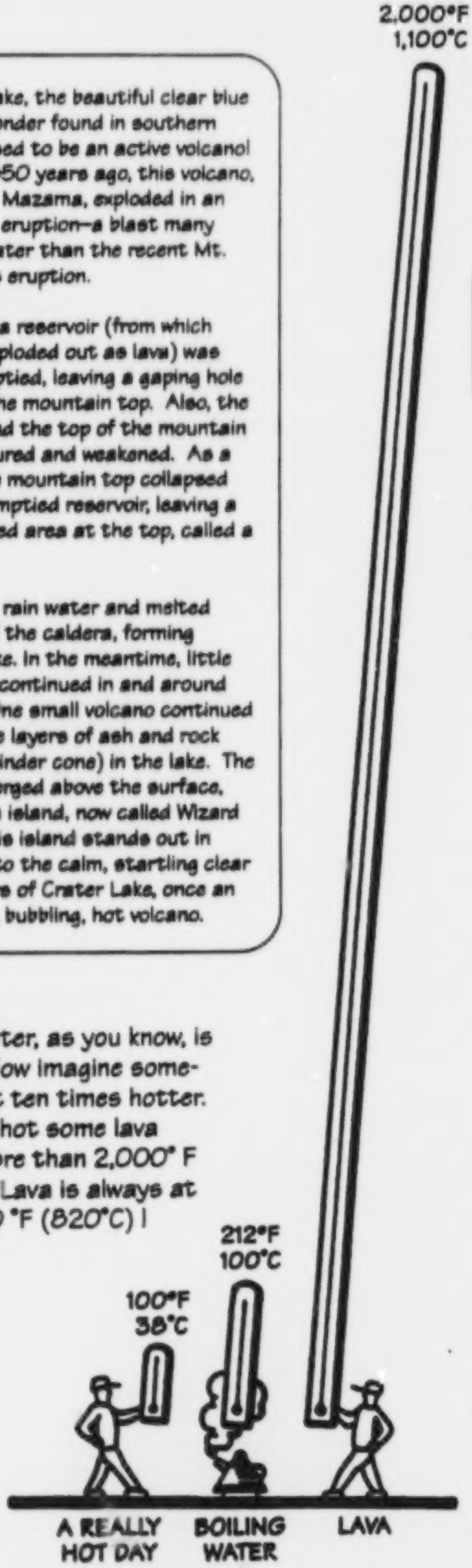
HOT OFF THE PRESS: VOLCANIC NEWS

Crater Lake, the beautiful clear blue natural wonder found in southern Oregon, used to be an active volcano! About 6,850 years ago, this volcano, called Mt. Mazama, exploded in an enormous eruption–a blast many times greater than the recent Mt. St. Helens eruption.

The magma reservoir (from which magma exploded out as lava) was partly emptied, leaving a gaping hole beneath the mountain top. Also, the rock around the top of the mountain was fractured and weakened. As a result, the mountain top collapsed into the emptied reservoir, leaving a bowl-shaped area at the top, called a caldera.

Over time, rain water and melted snow filled the caldera, forming Crater Lake. In the meantime, little eruptions continued in and around the lake. One small volcano continued to produce layers of ash and rock (called a cinder cone) in the lake. The layers emerged above the surface, forming an island, now called Wizard Island. This island stands out in contrast to the calm, startling clear blue waters of Crater Lake, once an enormous, bubbling, hot volcano.

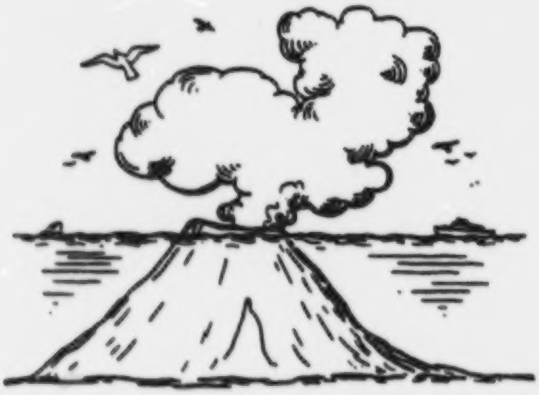
Boiling water, as you know, is very hot. Now imagine something about ten times hotter. That's how hot some lava can be - more than 2,000° F (1,100°C) ! Lava is always at least 1,500 °F (820°C) !



Imagine being the farmer near the village of Paricutín, Mexico, who found ash, smoke and lava pouring out of a crack in his fields on February 20, 1943. In one week, a volcano grew to the height of around 500 feet (150 meters)!

Some volcanoes literally blow their stacks! For example, Mount St. Helens in Washington blew off its top with a huge bang in 1980. In A.D. 79, an enormous explosion blasted the top off Mount Vesuvius, in Italy. The nearby town of Pompeii was buried in about 20 feet (6 meters) of ash, trapping thousands of people.

Speaking of loud bangs…on August 27, 1883, the volcanic island of Krakatoa, near Java, Indonesia, exploded with a noise that was even heard in Australia, 2,500 miles away. The ash and other compounds sent into the air affected the climate all over the world. Incidentally, the ash from the explosion blocked out the sun as much as 50 miles away!



Some islands are the tops of volcanoes. The Hawaiian Islands are one well-known example. Scientists even had the opportunity in 1963 to watch an island in the making when a volcano suddenly exploded out of the sea near Iceland, along the South Coast. It continued to grow, spewing out lava, which cooled and hardened until a new island was formed. It was called Surtsey, after the name of the Icelandic god of fire. Birds which landed on the barren island left seeds and spores from small plants. Eventually these began to grow and break down the lava rock into soil. (Volcanic ash is very fertile for growing plants.) Larger plants took root. This attracted more animal species, and so a new, living island soon developed.

EARTH SEARCH

STUDENT ACTIVITY

The following terms relating to the Ring of Fire can be found in this Earth Search. The words are spelled horizontally, vertically and diagonally.

CORE
MANTLE
TECTONICS
CONTINENTAL DRIFT
VOLCANO
MAGMA
CRUST
GEOTHERMAL
PLATES
GEYSER

S Q L M A G M A C B I Z T Y E G M O F R
D G C B A H J K O S R C D G R C E Y Z H
P A J M L I C S N K C P K A S B R U K M
V O L C A N O P M E Y L L Q N O Z U E A
U F X M L Y R X B C A A Q A C D G H S N
F A N I E L E O H R M A F B T L C T O T
G X L M O A C R X R Y L T F G E H N X L
E K H I E N O I E A N E Q R W A S O P E
Y I O S W J R H V X M F G E D B J R Y P
S S L T R O T R Q W S T Y N V A R E L A
E A S H C O N T I N E N T A L D R I F T
R W R C E L B T J B A Y R N I A W A Y F
M N Y G H Y W S K C X Z M J D I L R E M
E I F U N I L H U S X Y F T U W M B R B
F C N T A B P A U T E C T O N I C S V P

INSIDE THE EARTH

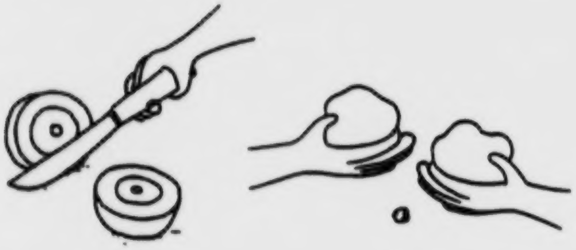
Art/Science Activity: Making a Model to Explain a Theory of the Composition of the Earth's Interior (No student worksheet)

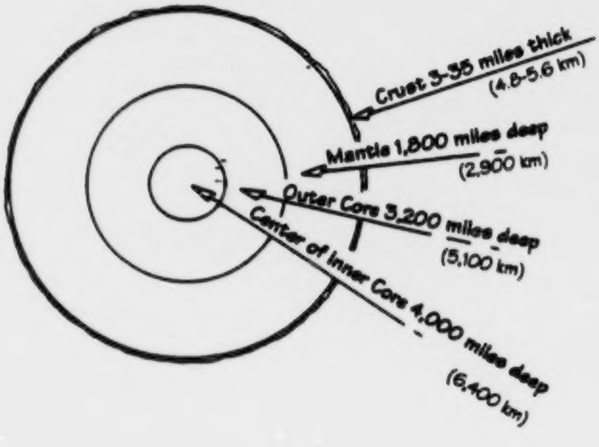
Materials:

- five colors of plasticene clay: red, orange, yellow, and blue and green swirled together
- kitchen knife

Directions:

Have students make a tiny ball the size of a pea out of red clay and put it into the center of a ball of orange plasticene clay about 1 & 1/4 inches (3 cm) in diameter. Have them put this ball inside a ball of yellow clay. Ask them to make the total diameter 2 & 1/2 inches (6 cm). Cover with a very thin shell of swirled blue/green clay. (Alternate crust idea: just roll "earth" in sand to coat.) Cut the spheres in half. Students can then explain the different sections. Management suggestion: Partners could make one ball together and then each get a half when the balls are cut.





AN EXPLOSIVE TOPIC

Demonstration: Why Some Volcanoes Explode (No student worksheet)

Materials:

- Plastic bottle of seltzer (clear)
- red food coloring (optional)

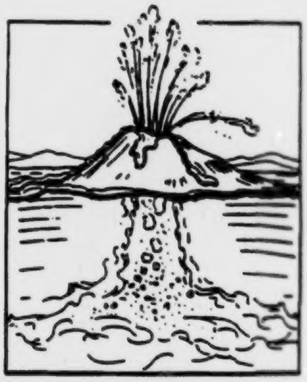
Directions:

1.) Gently unscrew the cap of the seltzer a little, reducing the pressure. Bubbles will appear. (Bubbles didn't show before because gases dissolve under pressure.) Tighten the cap and they will disappear.

2.) Take off the cap and add a little red food coloring.

3.) Quickly put the cap on tightly and give the bottle a gentle shake.

4.) Unscrew the cap a little, holding the bottle away from you. The liquid will fizz out as the pressure drops, simulating a volcanic eruption.



Explanation: Magma below the earth's crust contains a large amount of gases, primarily carbon dioxide. Because of the tremendous pressures under the surface, the gases are kept dissolved in the molten magma. When the magma finds a way to rise towards the surface, the pressure falls. With less pressure, the magma can hold less gas and so the gas is released. The gas first rises as very small bubbles. But as the pressure lowers as the magma rises, the bubbles get larger, expanding and pushing with explosive power. The seltzer also has carbon dioxide dissolved in it. The bubbles don't show when the bottle is capped because the contents are under pressure. When you release the cap, the pressure is lowered, and the water releases the bubbles. The bubbles expand and "explode", carrying the water with them, just as the gases in a volcano carry lava with them to the surface.

FOR THE TEACHER, cont.

Demonstration: Convection Currents
(No Student Worksheet)

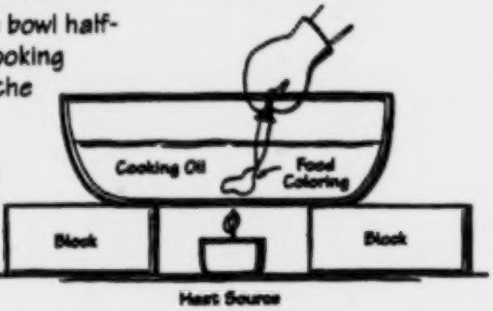
Materials:
- heatproof glass bowl
- votive candle
- food coloring (try different colors, some work better than others)
- cooking oil
- wooden blocks (larger than the height of the candle) (Instead of the candle and the block, a ring stand or other supportive device and a small alcohol burner or sterno burner would also work.)
- dropper
- mitt
- water
- goggles, if possible

Directions:

1.) Place the wooden blocks a few inches apart and place the votive candle between them.

2.) Rest the bowl on the blocks, making sure there is space between the bottom of the bowl and the candle top (about an inch or a little less).

3.) Fill the bowl half-full with cooking oil. Light the candle. **Warning:** Be careful of the hot oil!



4.) Drop a little food coloring into the middle of the bottom of the bowl. (Actually put the dropper right into the oil.)

5.) **Explanation:** As it heats up, blobs of food coloring escape and are caught up in the convection currents in the oil, which are rising to the surface when the oil heats and gets lighter. Once at the surface, the currents are spreading out because they are being pushed aside by the heated currents flowing up from below. The food coloring blobs move along with these currents. Then, as the currents cool, they get heavier and sink back to the bottom, carrying the food coloring with them. Magma acts in the same manner as the oil, only much, much slower.

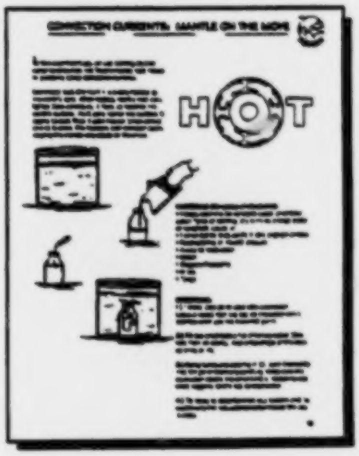
MOVING MANTLE

Science Activity: Mantle on the Move: Convection Currents (Student worksheet included)

Materials (Per group of students)
- 1 large, open-mouth straight sided jar (clear pyrex or canning jar such as large pickle or spaghetti sauce jar)
- 1 small bottle that will fit in the large jar or bowl
- food coloring or ink
- dropper
- a way to heat water
- mitt
- goggles, if possible

Directions:
Found on student work- sheet.

Management Suggestions:
Make sure that the bottles are small enough to fit well into the bowl or jar. Make sure water is very cold. Older students probably won't need help with lowering the bottle into the hot water.

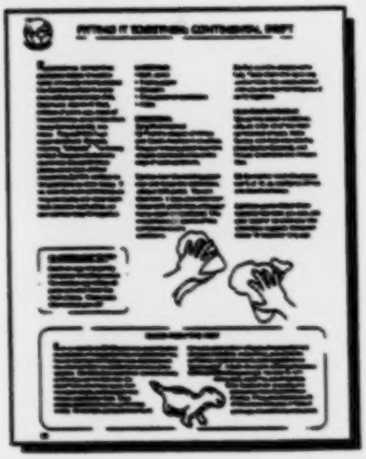


FLOATING PLATES

Activity: Fitting It Together: Continental Drift
(Student worksheet included)

Materials:
- Soft pencil
- Tracing paper
- Scissors
- Thick paper or cardboard
- Atlas

Directions:
Found on student worksheet.



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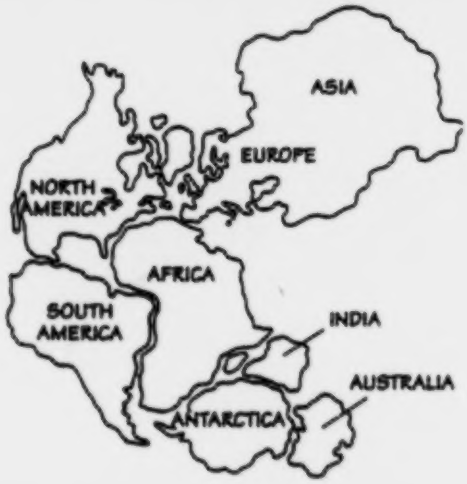
FOR THE TEACHER, cont.

Management Suggestions: You will note that there are two methods of doing this activity. In the simpler version, students trace Africa and South America only. This is very satisfying because they fit together very nicely. The more complicated method is included for those who have more time or want more challenge for their students. If at all possible, try to use an atlas with Mercator projections (cylindrical projections) which show the whole world on a single map with lines of longitude and latitude at right angles. Even though the continents near the poles are bigger than in reality, the pieces will be easier to trace and work with. You may want to make your own outlines for your students ahead of time. If you wish, simply enlarge the map above and cut it apart before class. Let your students to do the trimming. Or make one set and do this as a group activity on an overhead with the entire class.



WATER DOWN BELOW

Demonstrations: Porosity of Soil and Rocks
(No student worksheet)

Materials:
- glass
- dry soil
- water
- small rocks
- weighing scale
- jar of water

Directions: These demonstrations will give you an opportunity to show and talk about how rocks and soil have air spaces which water can seep into. Because of this we have groundwater, and hence geothermal reservoirs, geysers, hot springs, etc.

1.) Fill a glass three-quarters full of dry soil. Pack it tightly. Now fill the rest of the glass with water. Your students should notice bubbles coming out of the soil. Ask your students to explain where the bubbles come from. (Because soil is porous, it is filled with air pockets. As the water fills the little pockets, the air is pushed out.)

2.) To show how rocks can absorb water, gather several different kinds of small rocks such as granite or marble, cinders or pumice, sandstone or limestone. Weigh the rocks, then place them in a jar of water over night. The next day, weigh each rock and find the difference. Ask your students why some of the rocks weigh more. (Some rocks are more porous, have more air holes, and will absorb more water.)

Science/Math Activity: Water Down Below
(Student worksheet included)

Materials (Per group of students):
- materials to test (use whatever is handy – sand, soil, vermiculite, cleaning powder, gravel, etc.)
- large plastic drink bottle
- cheesecloth or muslin
- pouring pitcher
- measuring cup (big enough to easily hold the top portion of the drink bottle)
- elastic band
- scissors
- watch
- pen & notebook or recording page
- water

Directions: Found on student worksheet.

Management Suggestions: Be sure to use a measuring cup which is bigger than the drink bottles you use. The measuring cup holds the drink bottle "funnel" upright, but the fit shouldn't be tight. Otherwise it's very hard to get the bottle top out when it's full of wet materials. You will most likely want to cut the bottle tops off yourself to save time and prevent accidents. Have students perform three trials for each material. Have them find an average of their three trials. When all the groups are done, have each group share their average times with the class. Record these on the chalkboard, then have students find the average for each material. A chart or graph could also be made of the class averages.

FOR THE TEACHER, cont.

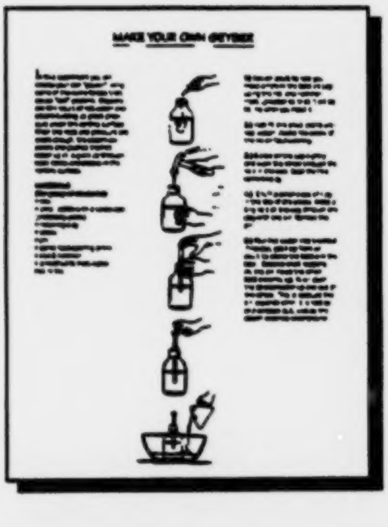
Science Activity:
Make Your Own Geyser
(Student Worksheet Included)

Materials
(Per group of students):

- bowl
- strong small bottle with a screw cap
- modeling clay
- a straw
- pin
- water
- some food coloring or ink
- large nail & a hammer
- a method to heat water
- hot mitts
- goggles, if possible

Directions: Found on student worksheet.

Management Suggestions: This can be done as a demonstration by you, or as a class activity, with the students broken up into cooperative groups of about four each. Each group doesn't need the nail, hammer, and hot water source. They can come to you for these in order to ensure more control over safety.



Cooking/Math Activity:
Baking a Volcano
(No student worksheet)

Materials:

- standard pastry (as for pies), made ahead
- strawberry jam
- rolling pins
- cutters
- knives
- spoons
- mini muffin pans or cookie sheet
- oven
- oven mitts

Directions:

1.) Roll out some pastry, and cut out circles for the base and the lid of your small volcanoes (tarts).

2.) Put one circle of pastry in each section of the muffin pan, then add a teaspoon of jam to each one.

3.) Put a pastry lid on each one and press down on the edges to seal them. Make a little hole in the center of each volcano. Make sure the lid presses down completely in the middle. (Alternative: use one piece of dough, put jam on and push in sides to make a "volcano," leaving a little hole.)

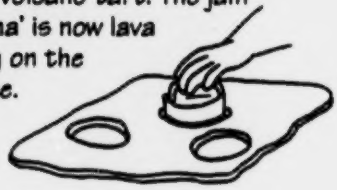
4.) Bake, using cookbook directions for tarts. When they are done, the jam "magma" will have erupted.

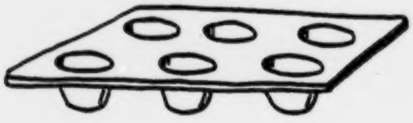
5.) Enjoy!

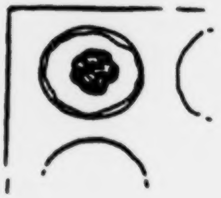
Management Suggestions: Small groups could do this with an aid or volunteer while the rest of the class is doing other activities.

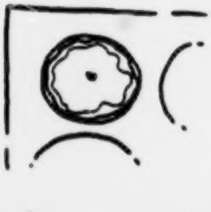
Math ideas: Use measurement and fractions when making the pie dough; try various amounts of jam using measurement (teaspoons, etc.) to see which "explodes" better – keep records of the results; out of each pan or a cookie sheet of tarts, count how many tarts "explode" vs. how many didn't and then make a ratio for each pan or cookie sheet.

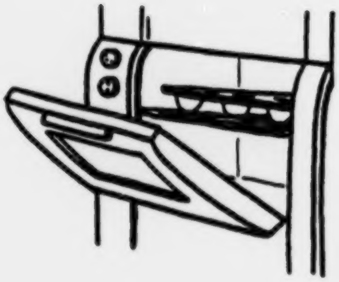
Explanation: The lid of the tart represents the Earth's crust, and the jam is the magma. The small hole is like a weak point in the crust. When the tart heats up, air and jam inside expand, creating pressure that forces the jam up and out of the volcano tart. The jam "magma' is now lava flowing on the surface.





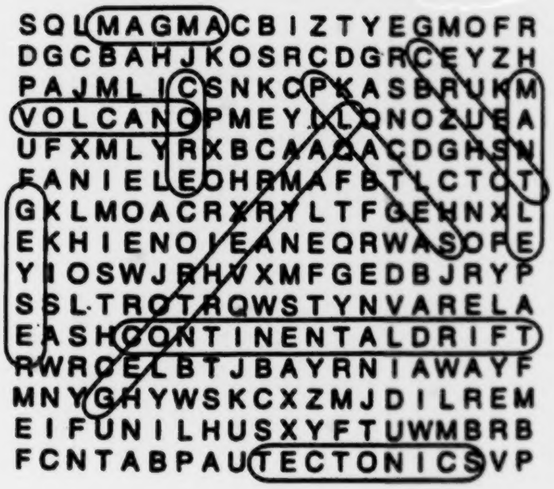






FOR THE TEACHER, cont.

Answers for Earth Search, page 29



S Q L M A G M A C B I Z T Y E G M O F R
D G C B A H J K O S R C D G R C E Y Z H
P A J M L I C S N K C P K A S B R U K M
V O L C A N O P M E Y L L O N O Z U E A
U F X M L Y R X B C A A Q A C D G H S N
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G K L M O A C R X R Y L T F G E H N X L
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NOTE: Earthquakes are a related topic not covered in this unit, but are often interesting to discuss. Here's an example of an activity and some suggestions.

Demonstration or Activity: Making Models of Fault Lines (No student worksheet)

Materials:

- Several different colors of modeling clay
- knife

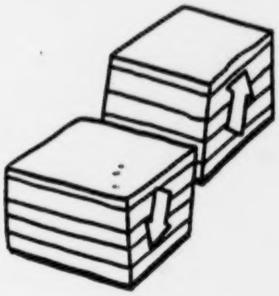
Directions:
Review with your students about how the earth's plates push together and pull apart, putting the rocks under tremendous stress. When the pushing gets too hard, the ground slides quickly. This causes an earthquake. The cracks that result are called faults.

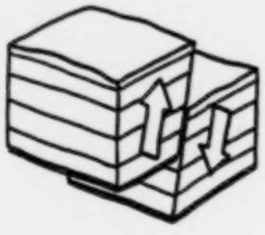
1.) Set several strips of alternating colors of clay on top of each other. These represent the different layers of rock called sedimentary layers.

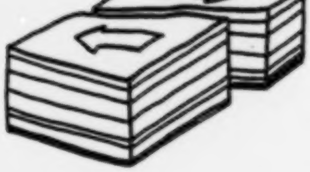
2.) Cut through the layers with the knife. Set the two pieces side by side.
3.) Pushing them together, slide the pieces past each other and move them up and down to demonstrate the different ways faults can break rock layers (see pictures).

Management Suggestions:
This could be done as a student activity so that students have their own clay and make their own models.

The same activity can be done using many-layered peanut butter and jelly sandwiches to demonstrate various types of rock layers. Students cut them and turn them into various faults and then eat them! The activity is found in the AIMS book Overhead and Underfoot.

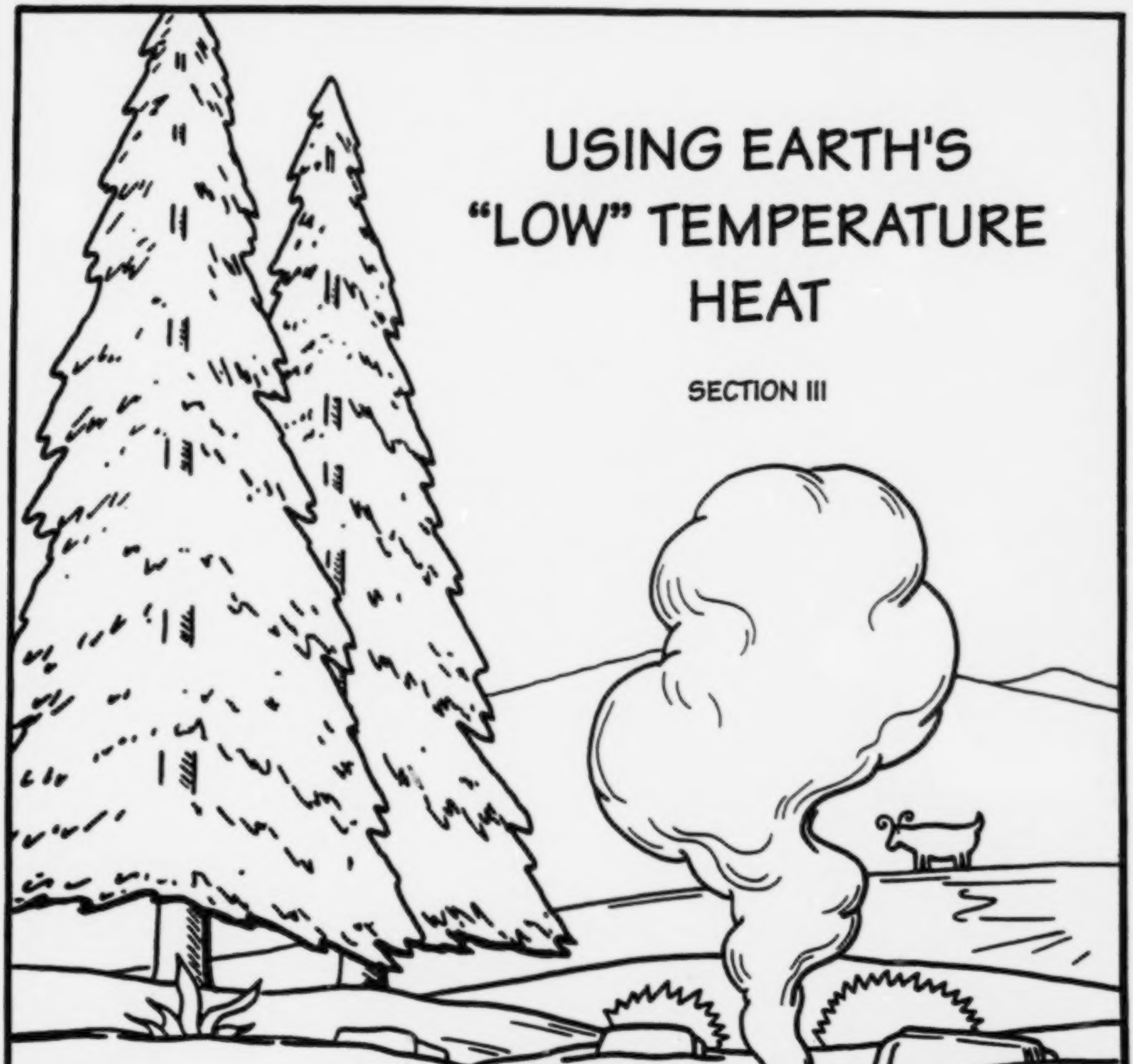






USING EARTH'S "LOW" TEMPERATURE HEAT

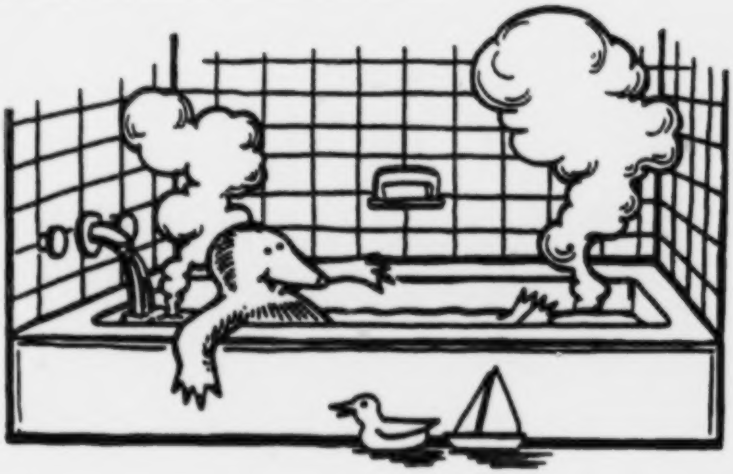
SECTION III



DIFFERENT USES FOR DIFFERENT TEMPERATURES

Once geothermal water reaches the surface, we use it in lots of different ways. Exactly how we are able to use it depends upon the temperature of the water. (Geothermal hot water can get hotter than 600° F [315° C]!). So when people talk about uses of geothermal energy, they often refer to "low temperature use" and "high temperature use." Geothermal water that is below 300° F (150° C) is called a low temperature geothermal resource. Don't let the name fool you; just because it is called "low" does not mean it isn't useful or that it isn't very hot!

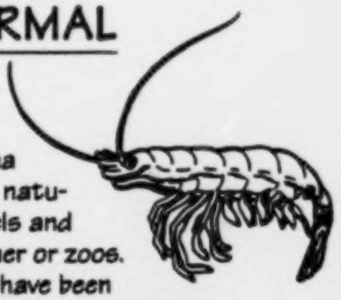
Think for a moment of all the ways hot water makes life better — baths, clean clothes and hot meals. Did you think of using hot water for growing tomatoes and cucumbers? or even fish? for heating houses or mining gold? Around the world, people living close to geothermal "hot spots" have discovered many ways to put lower temperature geothermal water from the earth to work.



SOMETHING'S FISHY!: AQUACULTURE USING GEOTHERMAL

(70°F - 90°F) (21°C - 32°C)

Geothermal aquaculture (the "farming" of water-dwelling creatures) uses natural warm water to speed the growth of fish, shellfish, reptiles, and amphibians. Warm water allows *aquafarmers* to grow water-dwelling animals throughout the year, regardless of the outside temperature. Typical geothermal aquafarms mix cold and hot water for the animals to live in. This kind of low temperature use of geothermal resources in China is growing so fast that fish farms alone cover almost 500 acres (2 million square meters). In Japan aqua farms use the earth's natu-warm water to grow eels and even alligators for dinner or zoos. Fish breeders in Idaho have been using geothermal water for many years raising delicious catfish and trout. Growers using this geothermal water in Idaho, Utah and Oregon raise tropical fish for pet shops. Icelandic aquaculturists are raising abalone in tanks heated by geothermal waters. The Icelanders hope to raise as many as two and a half million abalone a year.



EVERYBODY'S GETTING INTO HOT WATER: COMMUNAL BATHING AND BALNEOLOGY

(80° F - 105° F) (27° C - 41° C)

For centuries, people have been bathing in natural hot spring water for *therapeutic* reasons. This means that they felt that their health improved by soaking in the hot, relaxing mineralized water. Using mineralized water for medical therapy is referred to as *balneology*. Hot mineral springs also became attractions which drew people together. For some groups, the occasion has even taken on a spiritual meaning. Today, as long ago, people still bathe in geothermal hot springs for a variety of reasons.

In Europe, natural hot springs have been very popular health attractions. The first known *health spa* was established in 1326 in Belgium. There, a resort sprang up named "Espa", which means "fountain." The English word "spa" came from the name of this resort and is a word still in common use. All over Eurasia today, health spas are still very popular. In Russia, for example, citizens flock to one of the 3,500 spas located throughout the country. Baths where Beethoven, Bach, Chopin and Napolean once soaked are still in use in central Europe; "curative waters" are so valued there that they are legally protected.

On the other side of the globe , the Japanese have enjoyed a long tradition of social bathing - one which dates back to ancient Buddhist rituals. Japan is considered the world's leader in balneology. One Japanese city, Beppu, has 4,000 hot springs and bathing facilities that attract 12 million tourists a year.

For the people of Mexico, geothermal mineral hot springs have been well-known attractions since the days of Montezuma, emperor of the Aztec Empire. Today, in central Mexico alone, there are more than 100 major spas — drawing more than 10 million visitors every year. Mexico has so many hot springs that one Mexican state is named Aquas Calientes, the Spanish words for "hot waters."

Native Americans used hot springs many years ago for cooking, recuperation from warfare and for the stresses of old age. Later, when European settlers arrived in the New World, they saw the potential for developing these hot springs into health spas like those back home in Europe. Soon, people were flocking to the health resorts which "sprang up" across the United States. The largest spa in this country was in what is now Olympic National Park, in the state of Washington.

Today, there are still over 115 major geothermal health spas in the U.S. One well-known center, Calistoga, California, has been in existence since 1852 and is still a very popular attraction for tourists and health-seekers. Incidentally, Calistoga was, for a while, the home of Robert Louis Stevenson, author of Treasure Island and Kidnapped. He moved there in 1880 for, yes, ...his health!

HARVEST TIME, YEAR 'ROUND: GEOTHERMAL IN AGRICULTURE AND GREENHOUSES

(80° F - 200° F) (27° C - 93° C)

Geothermal resources are used worldwide to boost *agricultural* production. For hundreds of years, Tuscany in Central Italy has produced vegetables in the winter from fields heated by natural steam. Today in Tuscany vegetables and flowers are also *cultivated* in greenhouses warmed by geothermal hot water and steam. In Hungary, thermal waters provide 80% of the energy demand of vegetable farmers, and make Hungary the world's geothermal greenhouse leader.

Dozens of geothermal greenhouses dot the western United States, where we find geothermal heat used in lots of different ways to help vegetables, flowers and other plants grow better. For example:

- In Montana, a rose grower runs 55 miles (90 km) of pipe back and forth under his roses with geothermal water flowing directly through the pipes heating the surrounding soil. This same technique is used in other places, too, as in California where one hot spring not only pipes water to a nursery, but also to local mineral hot tubs and pools.

- In Idaho, there are greenhouses that take the heat from geothermal resources and transfer it into a forced air heating system. There, no matter what the outside temperature (which can get pretty low in Idaho!), poinsettias, lilies and chrysanthemums flourish inside. A similar system helps grow 5,000 roses a day (as well as bedding plants) in greenhouses located on a twenty-three acre spread in Animas, New Mexico.

- In Oregon, one greenhouse business uses geothermal heat for a combination of radiators, soil warming pipes and a snow melt system - an ingenious solution to three tricky problems all solved at one time with geothermal heat.

HARVEST TIME YEAR 'ROUND: THE EFFECT OF HEAT ON SEED GERMINATION AND PLANT GROWTH

As you have read, low temperature geothermal heat can be used to heat greenhouses and grow crops in otherwise wintery climates. In this experiment, you will test the idea that warmth can be beneficial to plant growth.

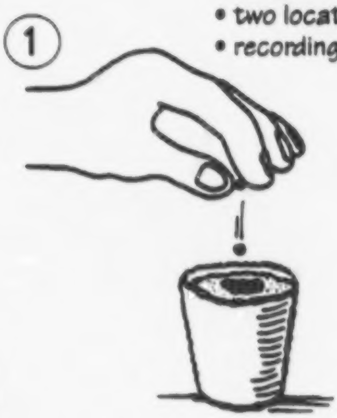
Remember that excessive heat is not helpful to plants. So, make sure the warm location you use is not too hot – for example, don't set your pot right on a radiator or other heat source.

You can add your own variations to this experiment, such as testing which location provides the ideal warmth for best growth.

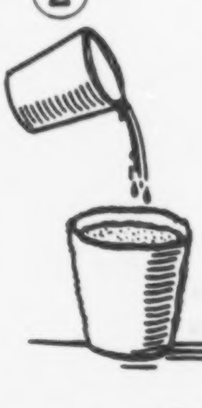
Materials (per student group):

- seeds (all of the same type)
- two small flower pots (such as the "dissolvable" kind)
- soil
- measuring cup for watering
- red liquid thermometer
- ruler
- two locations: cold and warm
- recording sheet or science notebook

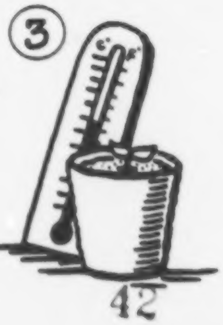
Directions:



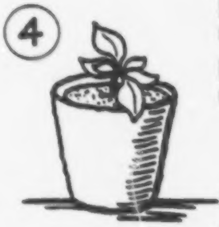
1.) Put the same amount of soil into two pots of equal size. Place the same number of identical seeds in each pot, at the same depth. Water each pot.



2.) Find or create two locations that have the same amount of light, but different temperatures: cold and warm. Check the temperature of each spot with the thermometer and make a note of each temperature. Make a note of the date you planted your seeds and the amount of water you gave them.

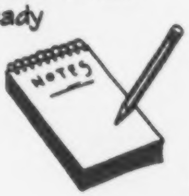


3.) Check your pots every day, or at an interval suggested by your teacher. Check the temperature to make sure it is approximately the same as before. Water if the pots are getting dry (to germinate, seeds needs to be constantly moist, but not drowning). Make notes of the date and any observations.



4.) Continue checking and making notes until you have germinated your seeds into plants. Once they've germinated, you can measure the plant growth with a ruler and make a note of that also.

5.) Be ready to share your information with the class. Each group's information could be collected, averaged, and made into a graph. Be able to discuss whether warmth had an effect on seed germination and plant growth. Be ready to discuss what this has to do with low temperature geothermal resources.



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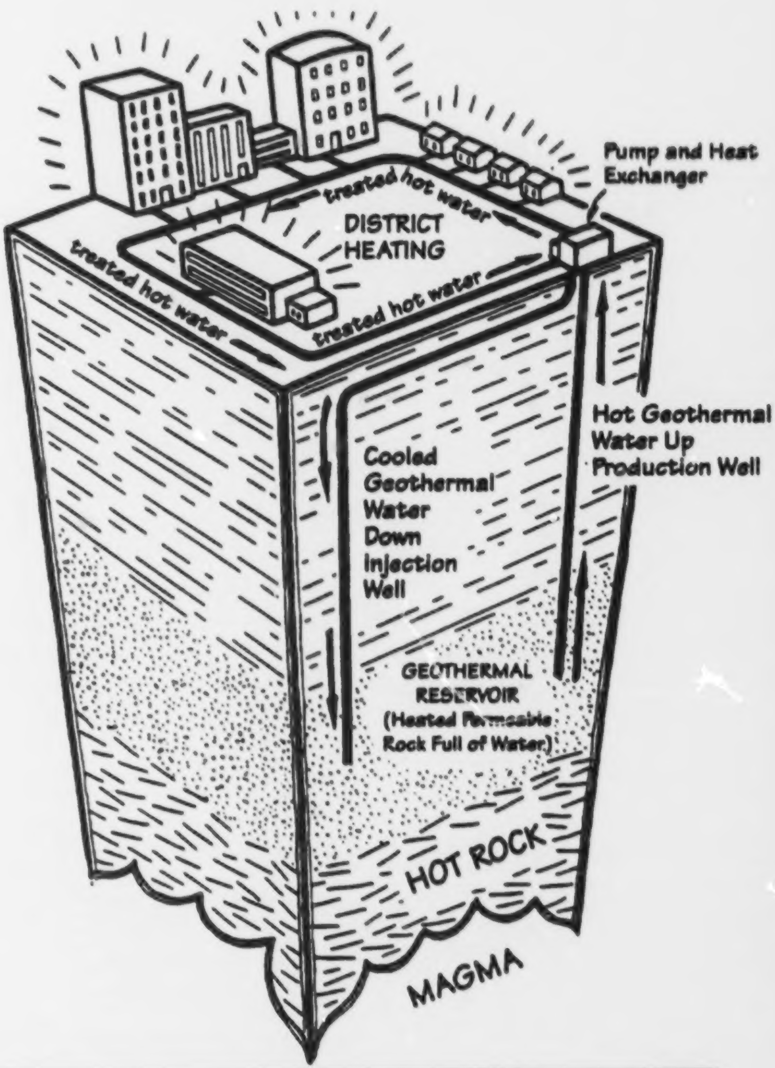
WARM ENOUGH? : USING GEOTHERMAL TO HEAT HOMES AND BUILDINGS

(80° F - 250° F) (27° C - 121° C)


treated hot water
DISTRICT HEATING
treated hot water
treated hot water
Pump and Heat Exchanger
Hot Geothermal Water Up Production Well
Cooled Geothermal Water Down Injection Well
GEOTHERMAL RESERVOIR (Heated Permeable Rock Full of Water)
HOT ROCK
MAGMA

Geothermally heated water can provide heat to homes, schools and offices – even to an entire business district. Individual buildings can even have their own personal geothermal heating system. (For example, over 500 residences in Klamath Falls, Oregon, have geothermal wells right in their front yards!) And, on the other hand, entire groups of buildings can be heated geothermally from one central facility. Then it is called *district heating.*

HOW GEOTHERMAL HEATS BUILDINGS

Many geothermal heating systems supply heat by pumping geothermal water – usually 140°F (60°C) or hotter – from beneath the earth's surface. The geothermal hot water is sent by pipes to a *heat exchanger,* which transfers the heat to treated city water that is then sent by pumps to the buildings. After it passes through the heat exchanger, the geothermal water is put back in the ground by means of an *injection well.* Underground, the water heats up again, so it can carry and transfer earth's heat to the surface over and over again.

WHAT IS A HEAT EXCHANGER ?

A heat exchanger is a device which allows heat to flow from a hot liquid to another cooler one without the liquids touching each other. In a geothermal heat exchanger, hot geothermal water (which might be mineralized and/or corrosive) is used to heat cooler water or other liquids. The kind of heat exchanger often used to help bring heat to homes and buildings is called a "plate" heat exchanger. In a plate heat exchanger, geothermal water and cooler water each flow separately through a series of flat hollow plates which are touching each other; so the heat from the geothermally-heated water transfers (or flows) through the metal plates and raises the temperature of the other water. This newly-warmed water then delivers its heat to a building (or buildings), while the geothermal water returns to its underground source where it is heated up again.

SOME EXAMPLES OF GEOTHERMAL DISTRICT HEATING

Because it is a clean, economical method of heating buildings, geothermal district heating is becoming more popular in many places, especially the United States, France and Iceland.

An unemployed well-driller in Boise, Idaho, invented the world's first modern geothermal district heating system in 1891. Sending hot water from a central plant, through pipes to and through residents' homes, his new company offered geothermal home heating for a flat rate of $2.00 a month, at a time when coal cost $7.00 a month. A large part of Boise is still heated with geothermal water. Other U.S. cities with geothermal district heating include: Klamath Falls, Oregon; Elko, Nevada; Reno, Nevada; Susanville, California and San Bernardino, California.

The Oregon Institute of Technology heats 11 of its buildings from 3 geothermal wells at a cost of about 6.3 cents per sq. foot of space to be heated. Compare that to the 60 cents per sq. foot that they would be spending if they were using conventional fuel such as coal or gas.

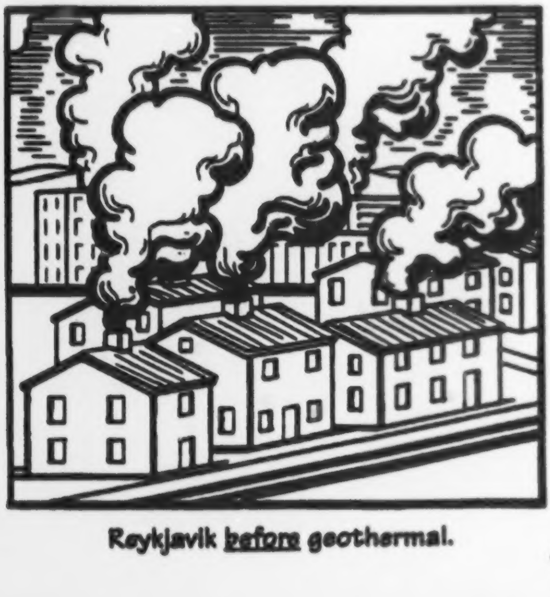
Downtown Klamath Falls uses geothermal energy to heat its central busines district.

Geothermal water at 212° F (100° C) is piped almost a mile to a central heat exchanger and control room. After heating city water, the geothermal water is injected back into the ground. Geothermally-heated city water goes through almost two miles (3 km) of pipe to heat many large office buildings. The district heating system also supplies a housing addition and is being extended out to a renovated theater.

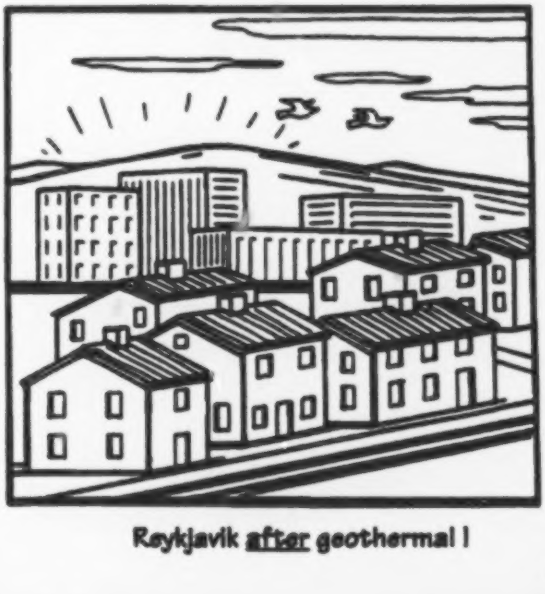
In China, between Tianjin and Beijing, many hundreds of apartments are heated by geothermal waters. The world's largest district heating system is in Iceland, home to many natural hot springs. It provides home heating to 140,000 residences in Reykjavik. Reykjavik, which means "bay of steam," used to be terribly polluted because of chimney smoke. Now it is one of the cleanest cities in the world!

WATCH OUT FOR THOSE MINERALS!

Some geothermal water contains natural chemicals and dissolved gases (including sulfur, calcium salts, carbon dioxide, hydrogen sulfide and others). Then it is referred to as *mineralized water.* In the past, mineralized water was difficult to use because it could form scale, or corrode pipes. Geothermal engineers can now design systems using pipes and equipment that are far less likely to corrode. This means that even more low and high temperature geothermal water is available for use than ever before.



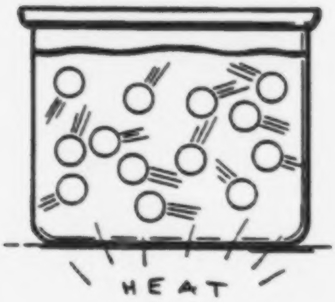
Reykjavik before geothermal.



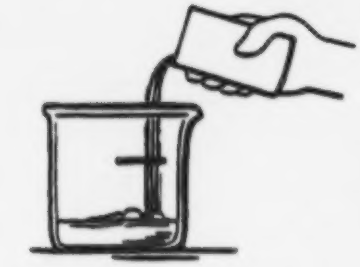
Reykjavik after geothermal!

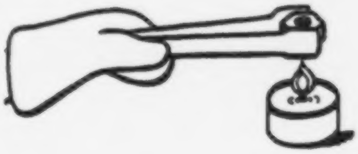
WATCH OUT FOR MOVING MOLECULES! : HEAT EXCHANGE

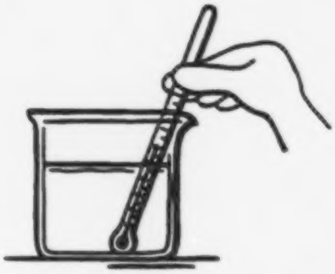
In this activity you will see how heat flows from a hotter material to a cooler one. To understand how this happens, first imagine very tiny particles called molecules which move faster when they are heated. These moving molecules always spread out as they bounce around, making other molecules around them move faster also. So, if something is hot, it always passes its heat to whatever is around it that is colder. This can be called heat flow, heat transfer, or heat exchange. (This happens every day when people put pots of food or water on a stove burner to heat. The heat goes from the burner, through the pan, to the food or water.)

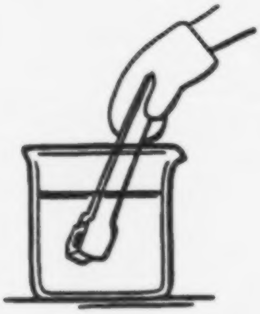


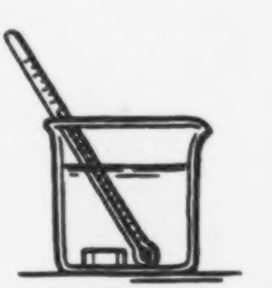
If ground water is near enough to hot rocks or magma, the heat is transfered to the cooler water, creating geothermal hot water. In a heat exchanger, one hot fluid passes its heat on to a cooler fluid.











Materials
(per group of students):
- water
- tongs
- non-flammable mitt
- goggles, if possible
- small beaker or heatproof container
- red liquid thermometer
- large metal nut
- heat source (such as alcohol or sterno burner)

Directions:

1.) Fill the beaker with about 50 ml of water.

2.) Wearing hot mitt and goggles (if available), use tongs to hold the metal nut in the flame for several minutes (exact time depends on size of nut).

3.) Take the temperature of the water in the beaker before you place the metal nut in the water. Record this information.

4.) Place the metal nut in the water using the tongs. Record the temperature of the water every 15 seconds for several minutes (or shorter if time doesn't allow). Observe what happens to the temperature of the water and be ready to discuss why the temperature of the water changes.

Safety Tip: To put out sterno flame, drop lid on top of sterno container using the tongs.

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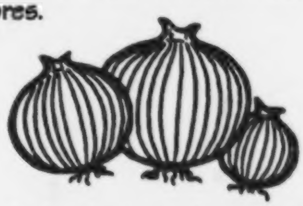
IT'S HEATING UP: USING GEOTHERMAL IN INDUSTRY

(200° F - 300° F) (93°.C - 149° C)

What do dried onions, bright rugs and breadboards have in common? They can all be produced with the help of geothermal resources. Here are some of the ways:

- Geothermal waters and gases have been used in Pacific rim countries for cloth dyeing and fruit drying. A company in Hawaii developed a process using a geothermal *drying chamber* to produce papaya powder for sale in health food stores.



- In Iceland, steam is used to dry diatomite, a fossil material used for filters and absorbents.
- In China, rug manufacturers use geothermal waters to wash their wool, believing more brilliant colors are produced this way.

- A business in New Zealand uses geothermal heat in manufacturing paper.
- At Brady Hot Springs and Empire, Nevada, geothermally-driven plants dehydrate heaps of onions and other vegetables. In Guatemala and the Philippines new facilities are being developed to use geothermal heat for food drying.
- Also in Nevada, thermal waters are used to extract gold and silver from ore.
- In Klamath Falls, Oregon, geothermal hot water was used to help *pasteurize* milk.

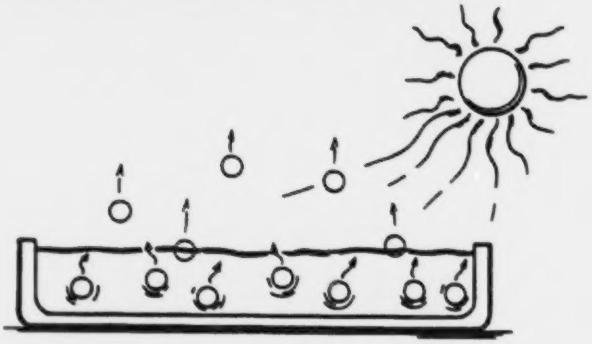
- Heat from geothermal steam is used to dry timber products in Japan and Taiwan, and in Hawaii to dry koa wood for fancy bread boards.

A GEOTHERMAL HOTLINE

When people around the world have questions about low temperature use of geothermal energy, they can call on the Geo-Heat Center, located at the Oregon Institute of Technology in Klamath Falls. For twenty years, the Geo-Heat Center has been providing geothermal information and helping people worldwide develop new ways to use geothermal resources. (See "Resources" in Appendix.)

IT'S HEATING UP: TESTING THE EFFECTS OF HEAT ON EVAPORATION

Evaporation is the changing of a liquid or a solid into a vapor state, the result of moving molecules. Evaporation can occur at room temperature or at higher temperatures. It can be speeded up by applying heat. In a liquid, molecules are in clusters that move around, bumping into each other. If the liquid is heated, the molecule clusters begin to move faster until they break away from each other and become a vapor.



The principle of evaporation is applied by companies around the world when they use low temperature geothermal heat to dry wood, cloth, food, and many other products. Geothermal heat is used, directly and indirectly, to provide the heat needed to speed up the evaporation process.

In this experiment, you will be testing the effects of heat on evaporation.

Materials:
- measuring cup
- two shallow pans
- warm location and cool place - both away from breezes
- hot plate or radiator
- two cloths of same material and size
- water

Directions

1.) Pour 1/2 cup water into each of two shallow pans (make sure the pans are identical). Put one in a warm place and the other in a cool place – away from breezes. Make a note of the time and date that you do this. Periodically check your pans and make a note of which pan of water evaporates first and when.

2.) The test can be speeded up by placing the "warm" pan over a heat source such as a hot plate or radiator. As before, make notes of times, dates, and any other observations.

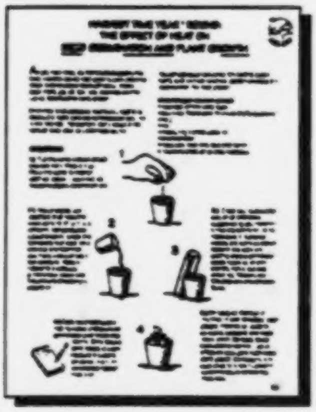
3.) Now get two cloths that are exactly the same material and size. Completley wet them with the same, measured amount of water for each. Repeat the procedure in step 1, either laying them both out or hanging them both up.

4.) Be ready to discuss your results and explain why this experiment applies to low temperature geothermal uses.

HARVEST TIME, YEAR 'ROUND

Science/ Math Activity: Testing the Effect of Heat upon Seed Germination
(Student Worksheet Provided)

Materials (per student group):
- seeds (all of the same type)
- two small flower pots (such as the "dissolvable" kind)
- packaged soil
- measuring cup for watering
- red liquid thermometer
- ruler
- two locations: cold and warm
- recording sheet or science notebook



Directions: Found on Student Worksheet

Management Suggestions:
Encourage students to be creative with this experiment. It can be turned into an investigation of the ideal warmth for the fastest seed germination, or a test of warmth's effect on plant growth once the plant has emerged.

A variation could be to make two small terrariums with identical plants and soil, putting one in a warm spot and one in a cold spot. Make sure light remains constant. Have the class observe the effects of warmth (or lack of it) on the plants.

Suggestions for integrating math into this activity include the following: Use metric and customary rulers to measure plant growth; have students record measurement results in a log. After the project is over students can calculate average plant growth and they can make graphs showing the growth rate over time.

WARM ENOUGH?

Social Studies Activity (no student worksheet): After reading the section on using geothermal to heat homes and buildings, have students investigate where the heat comes from for the following: their school, their homes, their parents' offices, any place else you can think of. Before doing the investigation, brainstorm all the possible energy sources that could be providing their heat (hydro, wind, solar, nuclear, fossil fuels, geothermal, wood, butane, etc.) Brainstorm ways that they can find out what energy source their heat comes from such as asking their parents, calling the local power company, and so on. Follow-up in any way you think appropriate – verbal sharing, written reports, bulletin boards with pictures, etc.

WATCH OUT FOR MOVING MOLECULES

Science Activity: Heat Exchange
(Student worksheet included)

Materials: (per group of students):
- water
- tongs
- non-flammable mitt
- goggles, if possible
- small beaker or heat proof container
- red liquid thermometer
- large metal nut
- heat source (such as alcohol or sterno burner)

Management Suggestions: Be sure to emphasize that the metal nut is a substitute for hot rock in the earth. As a follow-up to this activity, students could construct a line graph of the water temperature over time.

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IT'S HEATING UP

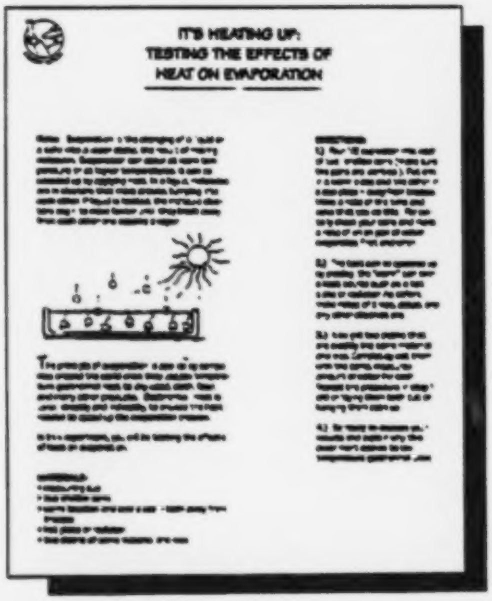
Science Demonstration:
The Effects of Temperature on Evaporation
(Student Worksheet Provided)

Materials:
- measuring cup
- two shallow pans
- warm location and cool place - both away from breezes
- hot plate or radiator
- two cloths of same material and size

Directions: Found on student worksheet.

Management Suggestions:
You might want to have different groups do different portions of this experiment. This activity can also be done as a class project.

If you have a food dehydrator that uses heat, you might want to demonstrate the use of heat to speed the drying process. Or, using a microwave to dehydrate herbs can give a new twist to dehydrating.



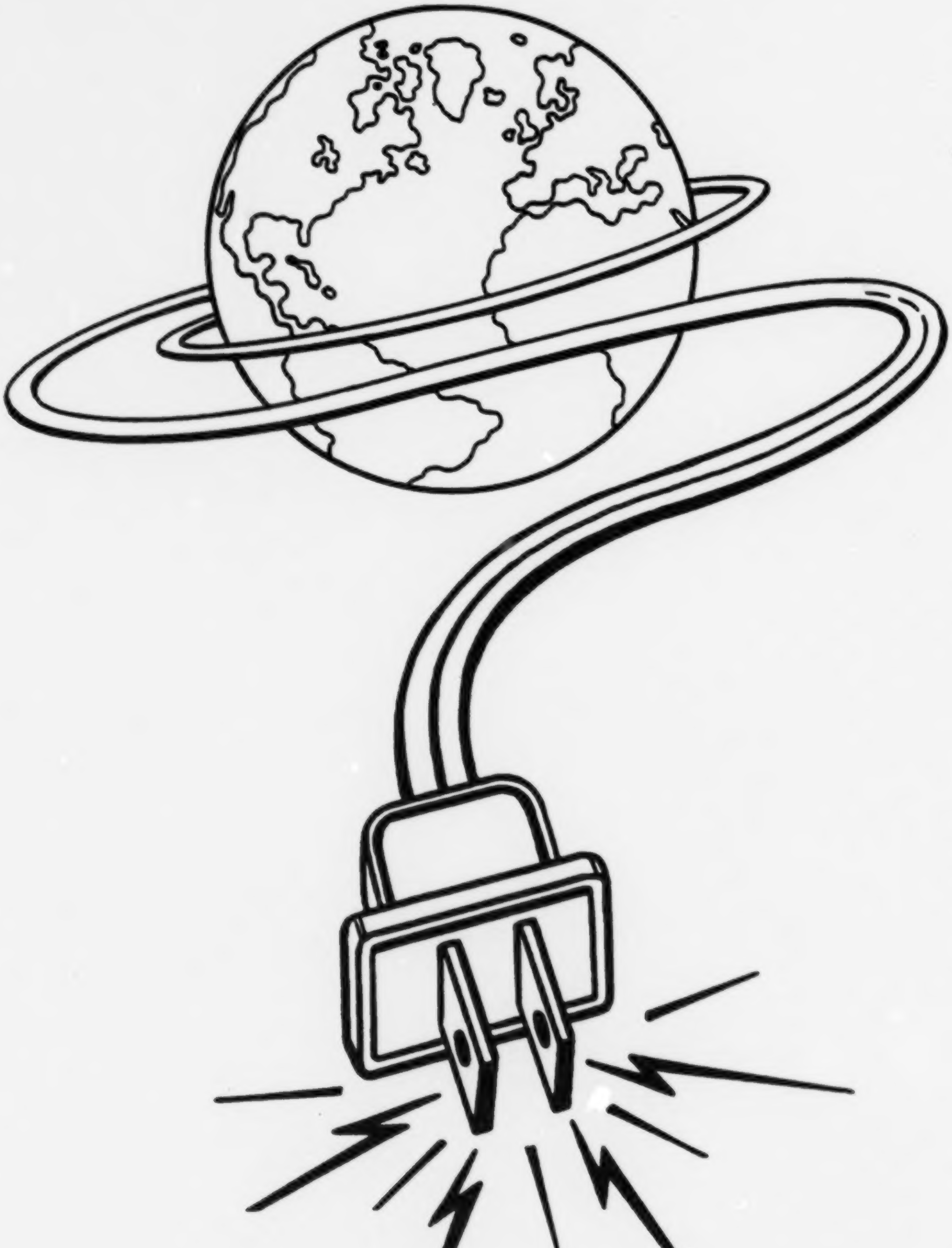
IT'S HEATING UP:
TESTING THE EFFECTS OF
HEAT ON EVAPORATION

Social Studies / Science Activity
(no student worksheet):

If low temperature geothermal resources are being utilized in your area, have some students research how the low temperature geothermal resources are being used. Perhaps you could visit a place where they are being used or invite someone from the industry to come and talk with your class. If you have problems arranging for a speaker in your area, contact the Geothermal Education Office for help. (See Resources, Section VII)

GENERATING ELECTRICITY: USING HIGH TEMPERATURE GEOTHERMAL AND OTHER RESOURCES

SECTION IV



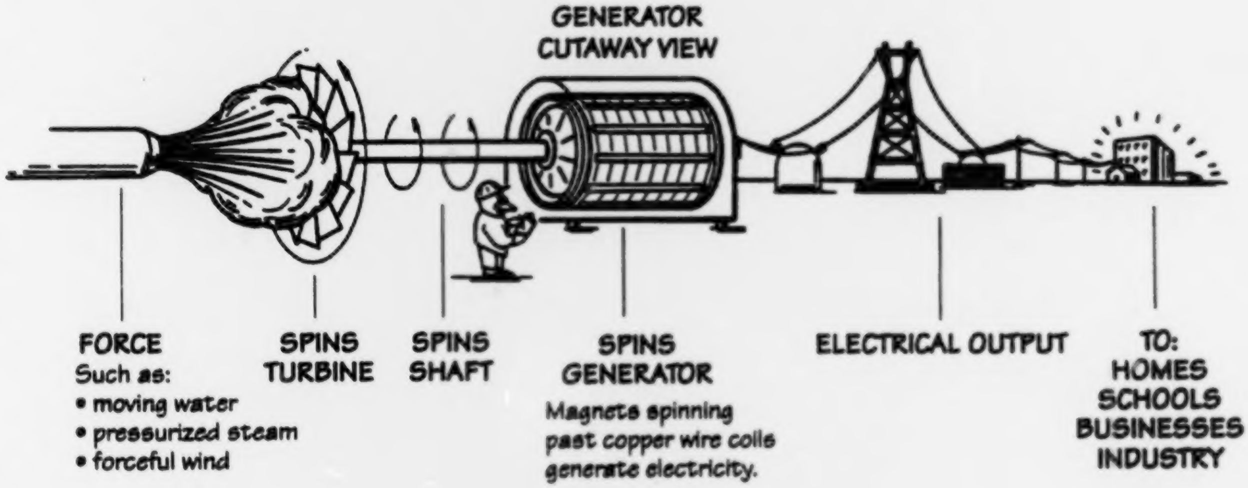
PRODUCING ELECTRICITY WITH A TURBINE GENERATOR

All of the electricity we use comes from energy resources, both renewable and non-renewable. These resources include water and steam, the wind, fossil fuels, the sun, uranium and other elements from the earth, and wood and other substances produced by living things (called biomass). Renewable and nonrenewable energy resources generate electricity in a variety of ways, frequently providing the force needed to turn turbines which run electricity generators.

Turbines were first used to produce electric current in the 1880's. There are many turbine designs, but they all operate on the same principle: a force - such as moving water, pressurized steam or steady wind - hits blades attached in a circle around a central shaft or long rod. The force causes the blades to move, which makes a shaft spin.

This turbine shaft is attached to huge magnets that spin between coils of copper wire. Magnets are surrounded by a *magnetic field.* As the magnets move past the wire coils, an *electric current* is generated: the attraction of the magnetic field makes tiny particles called *electrons* move. Electrons are so tiny that they cannot be seen except with special instruments, but when they move it creates electricity.

Altogether, the magnets, wires, and rod make up a device called a generator. A generator, turbine, and source of power is a power plant, no matter how large or small. Even a single windmill can be thought of as a power plant. But usually when we think about the generation of electricity we picture a huge power plant, filled with enormous turbine generators, humming with force and energy.


GENERATOR
CUTAWAY VIEW
FORCE
Such as:
• moving water
• pressurized steam
• forceful wind
SPINS
TURBINE
SPINS
SHAFT
SPINS
GENERATOR
Magnets spinning past copper wire coils generate electricity.
ELECTRICAL OUTPUT
TO:
HOMES
SCHOOLS
BUSINESSES
INDUSTRY

WHAT HAPPENS INSIDE A GENERATOR:

Producing Electricity Using a Magnet

Turbine electricity generators use powerful magnets and huge wire coils to produce electricity. The electricity is generated by either the rapid spinning of the magnets inside coiled wires or the spinning of coiled wires inside of enormous magnets. The process works either way. Turbines, turned by a force such as steam, provide the spinning power.

Magnets are surrounded by a magnetic field that is very "attractive." When a strong magnet (such as a bar magnet with "north" and "south" poles) moves, it's magnetic field changes. When wires are connected to make a complete pathway (a "circuit"), a changing magnetic field will produce an electric current in these wires if the magnet gets close enough. Wrapping the wires into coils will increase the amount of electric current. Moving the coils instead of the magnet also works.

You can test the idea that magnets can produce an electric current by doing the following demonstration.

Materials:
Per student group

- *enough insulated copper bell wire to make a fifty-loop coil larger than the magnet*
- *a strong bar magnet with "poles"*
- *a current detector (galvanometer)*

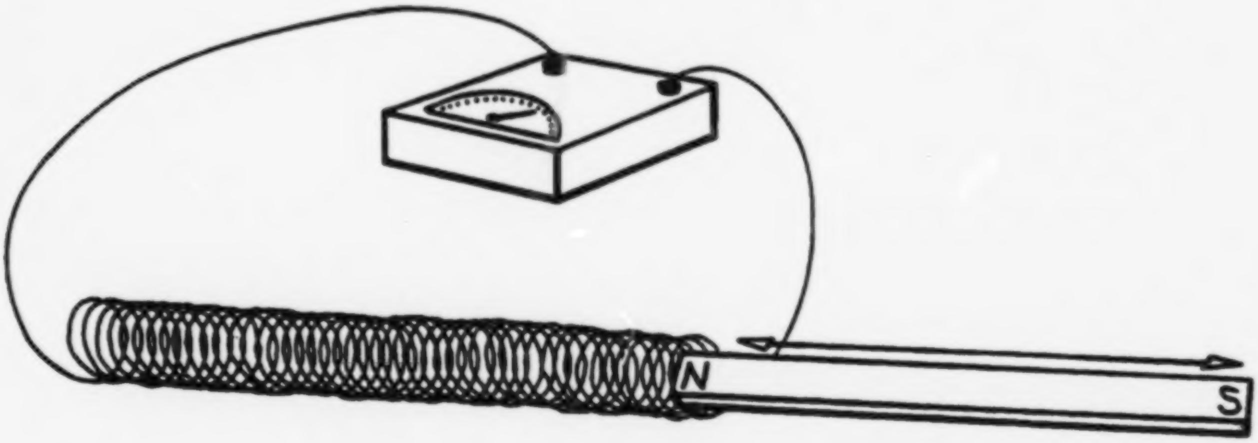
Directions:

1.) Make a fifty-loop coil of the insulated copper wire through which you can slip the magnet.

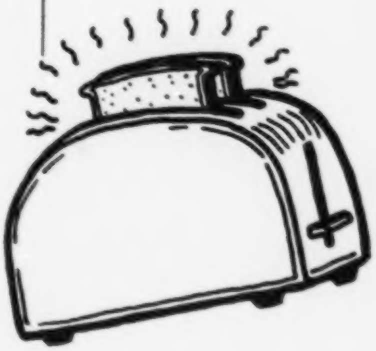
2.) Attach the end wires of the coil to the galvanometer.

3.) Move one pole of the magnet in and out of the coil. There should be movement in the galvanometer.

4.) Then try holding the magnet stationary and moving the coil over one of the magnet poles.



Understanding Electrical Terms



Electrons traveling through a wire can be compared to water molecules flowing through a pipe. *Voltage* (expressed in volts, named after the scientist Allessandro Volta) is what pushes the electrons, like pressure pushes the water. Current is the flow of electric charge. It is the amount of electrons flowing past a certain point per unit of time. The amount of current flowing in a wire in a given amount of time is expressed as *amperes* (or "amps"), named after Andre Marie Ampere). It is a rate of current flow similar to describing water flow in gallons per minute or liters per second. A watt is a unit of power and is the rate energy is used in electrical devices. One watt is the rate of current flow when one ampere is "pushed" by one volt. One watt is needed by a typical string of Christmas lights. A *megawatt* (one thousand kilowatts) is equal to one million watts, the amount needed to provide power (in the United States) to the homes of 1,300 people.

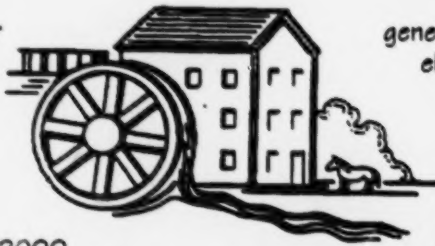
Electricity to Your Home

Electricity is sent from power plants to surrounding communities through power lines like the ones you see every day. If the electricity is traveling far, then high voltage is maintained. Voltage is the force with which a source of electric current moves electrons (remember, moving electrons are responsible for electric current). For safety, these high voltage power lines are installed on very high towers. Then, when the electricity arrives close to its destination, it goes through a *transformer* which "steps down" the voltage for use in homes and other buildings (in the U.S., this is usually 110 volts.) The high-voltage electricity may also be allowed to flow directly into certain machines and electric streetcars or monorails which can handle it directly, without a "stepdown."

PRODUCING ELECTRICITY *WITHOUT* STEAM

Many power plants use the force of steam to generate electricity, but as you will see steam isn't the only resource that can be used. There are a number of ways to generate electricity without using steam.

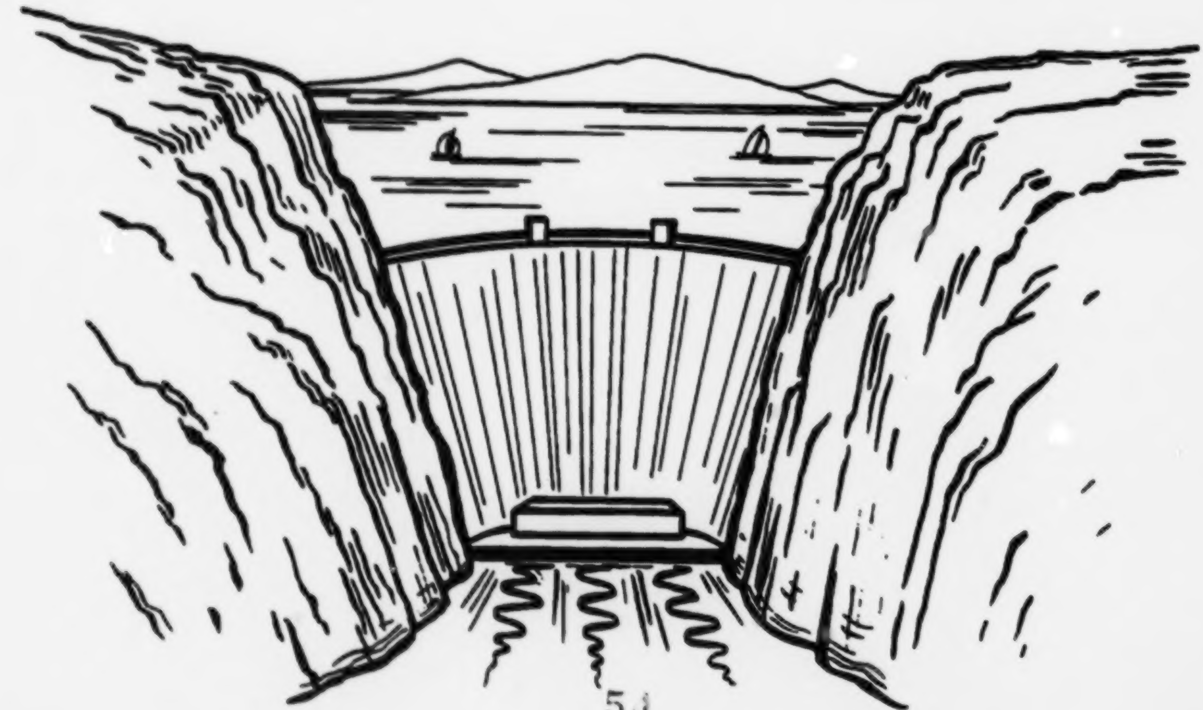
TURBINES AND WATER POWER



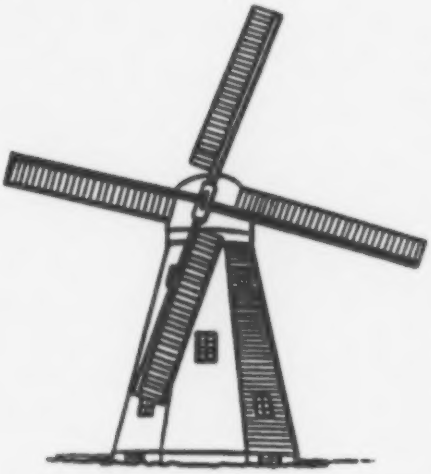
Machines that rely on the power of moving water have been in use since the times of the great *Library of Alexandria* (a center for study and experimentation, located in the capital of Egypt during the rules of the Persians, Greeks and Romans). There, over 2000 years ago, scientists worked with inventions such as the water clock. Since early 100 A.D., many types of water wheels have been invented, using buckets or paddles which catch the moving force of water, making the wheels turn. In the early 1800's water wheels were modified into turbines with curved, slanting blades like those of a propeller.

Falling water has a great deal of force which can be used to turn turbines. When rivers are dammed and used to run huge turbines and generators, then we have a hydroelectric power plant (remember, hydro = water). The "fuel" in these plants is the force of the water; no fuel is burned. Water is also considered a renewable resource. Hydroelectric power plants presently produce more electricity than any other renewable resource. In the Pacific Northwest, for example, more than 50% of all electric energy is generated with hydropower.

Another, but limited, use of water power is a method that harnesses the energy of ocean tides, called tidal energy. Tidal energy uses the force of incoming and outgoing water (tides) to flow through turbines and generate electricity. It is being studied as a future energy source.

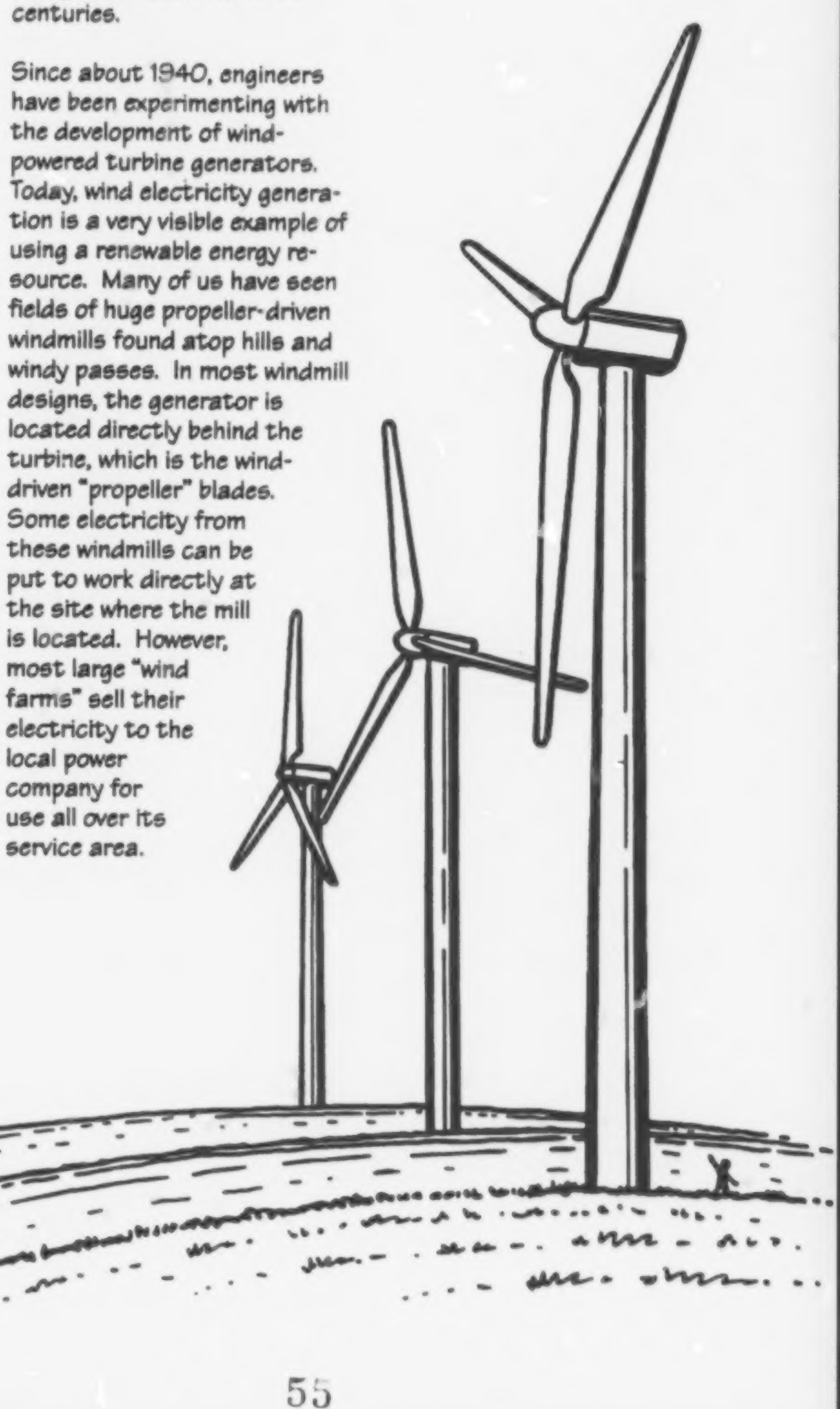


WINDMILLS AND WIND POWER



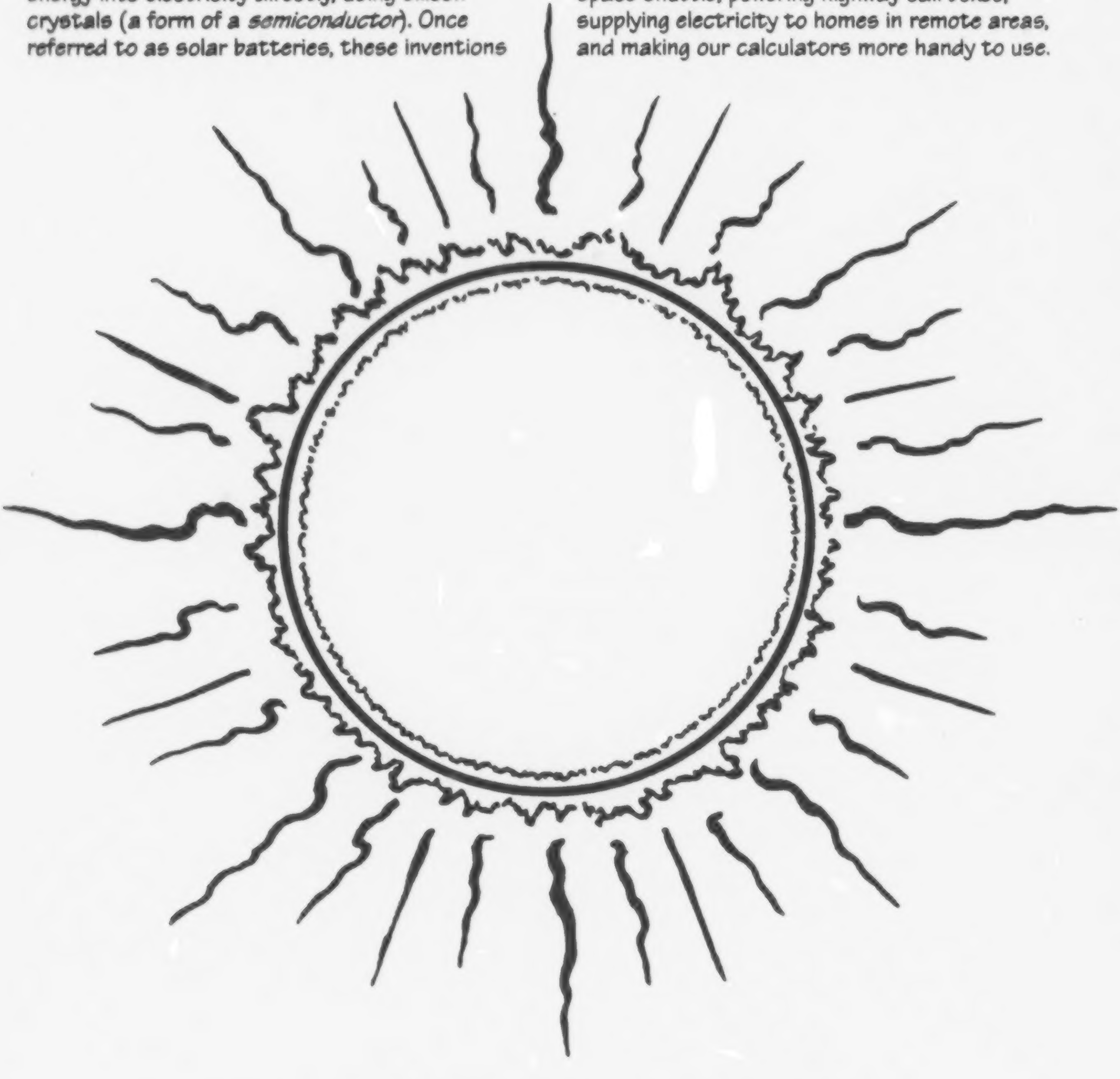
Windmills use the force of the wind the way turbines use the force of falling water. Windmills use sails or propeller-like devices to catch the power of the wind. The idea for doing this dates back to around the 10th century A.D. in Persia. There, whole fields of windmills, which were used to lift water for irrigation, were located in vast plains where powerful winds blew for months at a time. These windmills always faced the same direction. Then, around the 12th century A.D., Europeans invented windmills which could face into whichever direction the wind was blowing. This made them far more useful and versatile. All over the world, from Holland to Greece to the United States, windmills have been grinding grain, pumping water, charging batteries, and doing other useful work for centuries.

Since about 1940, engineers have been experimenting with the development of wind-powered turbine generators. Today, wind electricity generation is a very visible example of using a renewable energy resource. Many of us have seen fields of huge propeller-driven windmills found atop hills and windy passes. In most windmill designs, the generator is located directly behind the turbine, which is the wind-driven "propeller" blades. Some electricity from these windmills can be put to work directly at the site where the mill is located. However, most large "wind farms" sell their electricity to the local power company for use all over its service area.



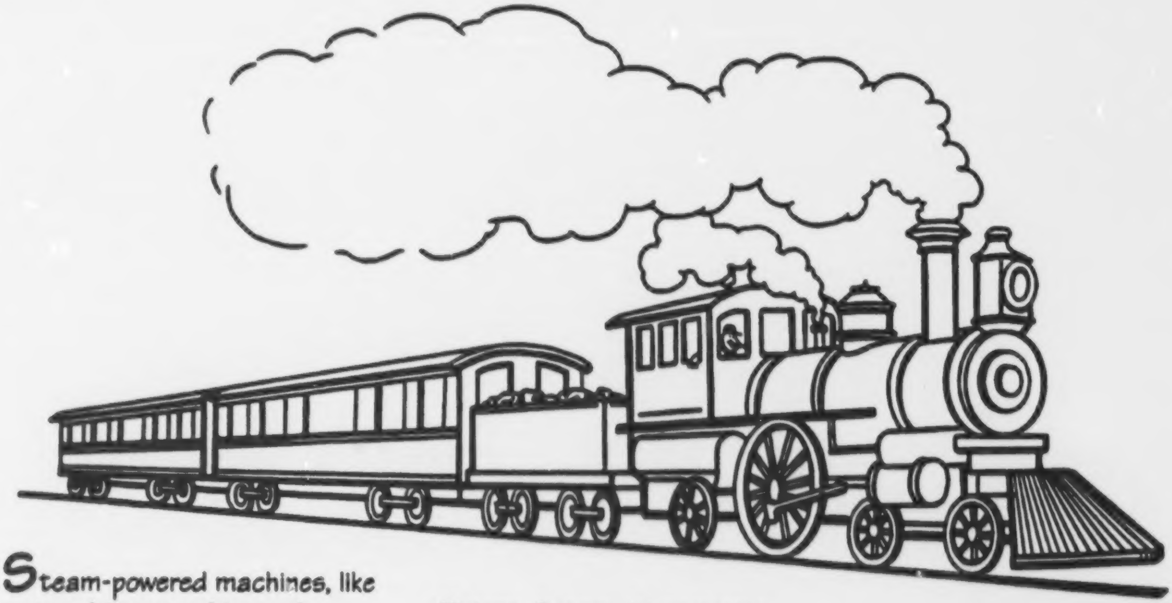
SOLAR CELLS AND SUN POWER

Since the dawn of time, energy radiating from the sun has been making life easier for humans: growing plants, warming the earth, heating the air and water ... the list goes on and on. In the 1950's engineers invented a way to convert solar energy into electricity directly, using silicon crystals (a form of a *semiconductor*). Once referred to as solar batteries, these inventions grabbed the light of the sun to power the electronic equipment of the first satellites. Now referred to as solar cells, or *photovoltaic cells*, these amazing devices are put to work in a variety ways including running part of the space shuttle, powering highway call boxes, supplying electricity to homes in remote areas, and making our calculators more handy to use.

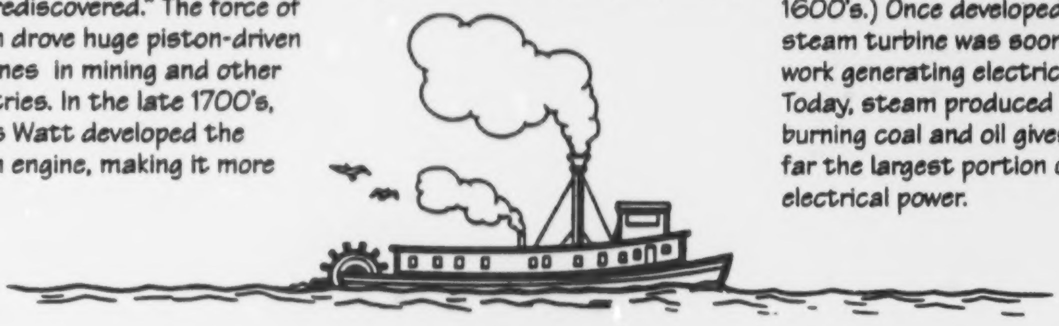


Electricity can also be generated using the sun's energy by heating water to produce steam at a solar thermal power plant (See p. 55).

PRODUCING ELECTRICITY *WITH* STEAM



Steam-powered machines, like water-driven machines, also date back to the days of the Alexandria Library, although the power of steam didn't actually enjoy widespread use until 1700. Then steam's force was "rediscovered." The force of steam drove huge piston-driven machines in mining and other industries. In the late 1700's, James Watt developed the steam engine, making it more efficient. Steam-driven trains, paddle wheel boats, ocean liners, and passenger carriages soon followed. Up to this point, steam was not used to generate electricity, but it was certainly kept busy! The first modern steam-driven turbine was invented by a Swedish dairy operator in 1882. (The idea was suggested by an Italian engineer in the late 1600's.) Once developed, the steam turbine was soon put to work generating electricity. Today, steam produced by burning coal and oil gives us by far the largest portion of our electrical power.



WHAT IS STEAM?

Steam is the vapor form of water and develops when water boils. It is made of very tiny heated water particles called *molecules* which are bouncing around and bumping into each other at very high speeds. These heated water molecules are also spreading out and expanding in every direction they can. If we confine or trap water in a container, with a pipe as an opening, and heat the water to steam, it will create great pressure in the container and will rush out the pipe with a great deal of force. This force (the "power" of steam) can be put to work turning a turbine connected to an electricity generator (see p.48).

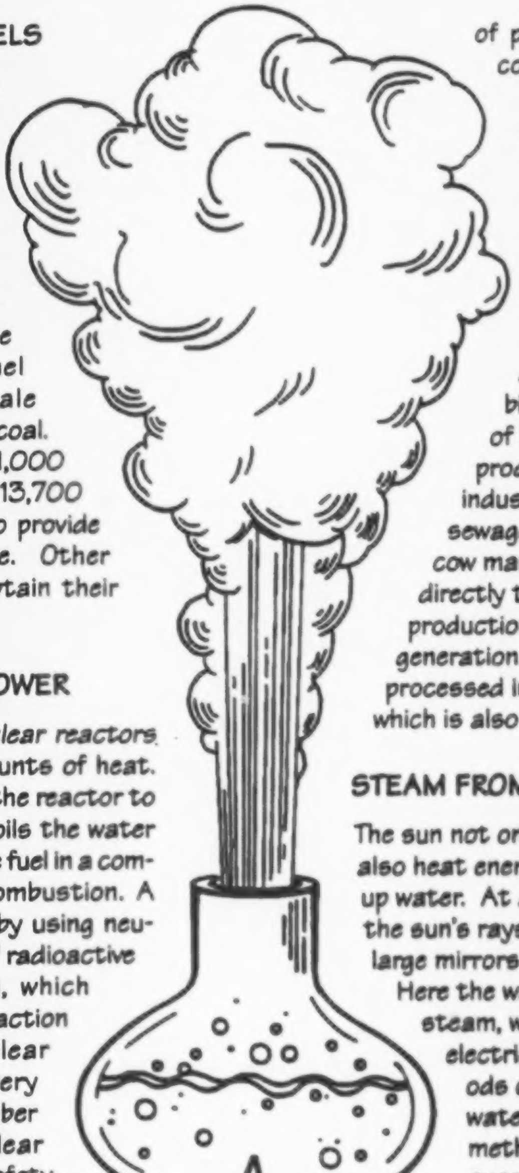
Steam can be either manufactured or natural :

"Manufactured" means we make it. To make steam we need to boil water, and this means we need a heat source.

Natural steam is the kind that comes from geothermal resources.

GENERATING ELECTRICITY FROM *MANUFACTURED* STEAM

In order to manufacture steam we need fuels to heat up the water. These fuels include some renewables and some nonrenewables: fossil fuels, nuclear fuel, biomass (biofuels) and, again, our friend the sun.



STEAM FROM FOSSIL FUELS

Fossil fuel power plants burn fuels such as coal, oil, and *natural methane gas*. Fossil fuels must be burned (combusted) in order to release their energy, mostly in the form of heat. This heat is then used to boil water, making steam that spins turbine generators. Most fossil fuel power plants are large-scale operations. Many of them use coal. A typical power plant (about 1,000 megawatts) might burn up to 13,700 tons of coal a day in order to provide the needs of a million people. Other types of fossil fuel plants obtain their heat from oil or natural gas.

STEAM FROM NUCLEAR POWER

Nuclear power plants use *nuclear reactors* which produce enormous amounts of heat. This heat is transferred from the reactor to a steam generator where it boils the water to steam. Nuclear reactors use fuel in a completely different way from combustion. A nuclear reaction is produced by using neutrons to "split" the nucleus of radioactive materials such as uranium, which results in a controlled chain reaction that releases energy. Nuclear power plant technology is very complicated; it includes a number of ways to control the nuclear reaction and provide for the safety of plant workers and neighboring communities.

STEAM FROM BIOMASS (BIOFUELS)

Steam for electricity can also be produced by using substances that come from living things, called biomass (or biofuels). The oldest and most common form of biomass is wood. Other forms of biomass include other forest products, crops, agricultural and industrial wastes, algae, and sewage and solid wastes (including cow manure!). Biofuels can be burned directly to provide heat for steam production that is used in electricity generation. Some biofuels can also be processed into ethanol and methanol which is also burned as a fuel.

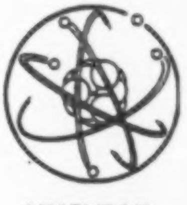
STEAM FROM THE SUN

The sun not only produces light energy, but also heat energy which can be used to warm up water. At a solar thermal power plant the sun's rays can be focused by rows of large mirrors directly on a large water tank. Here the water gets hot enough to make steam, which can then run the turbine electricity generators. Other methods of using the sun's heat to boil water also exist, but this direct method seems to be the most successful so far.

COAL

OIL

NATURAL GAS

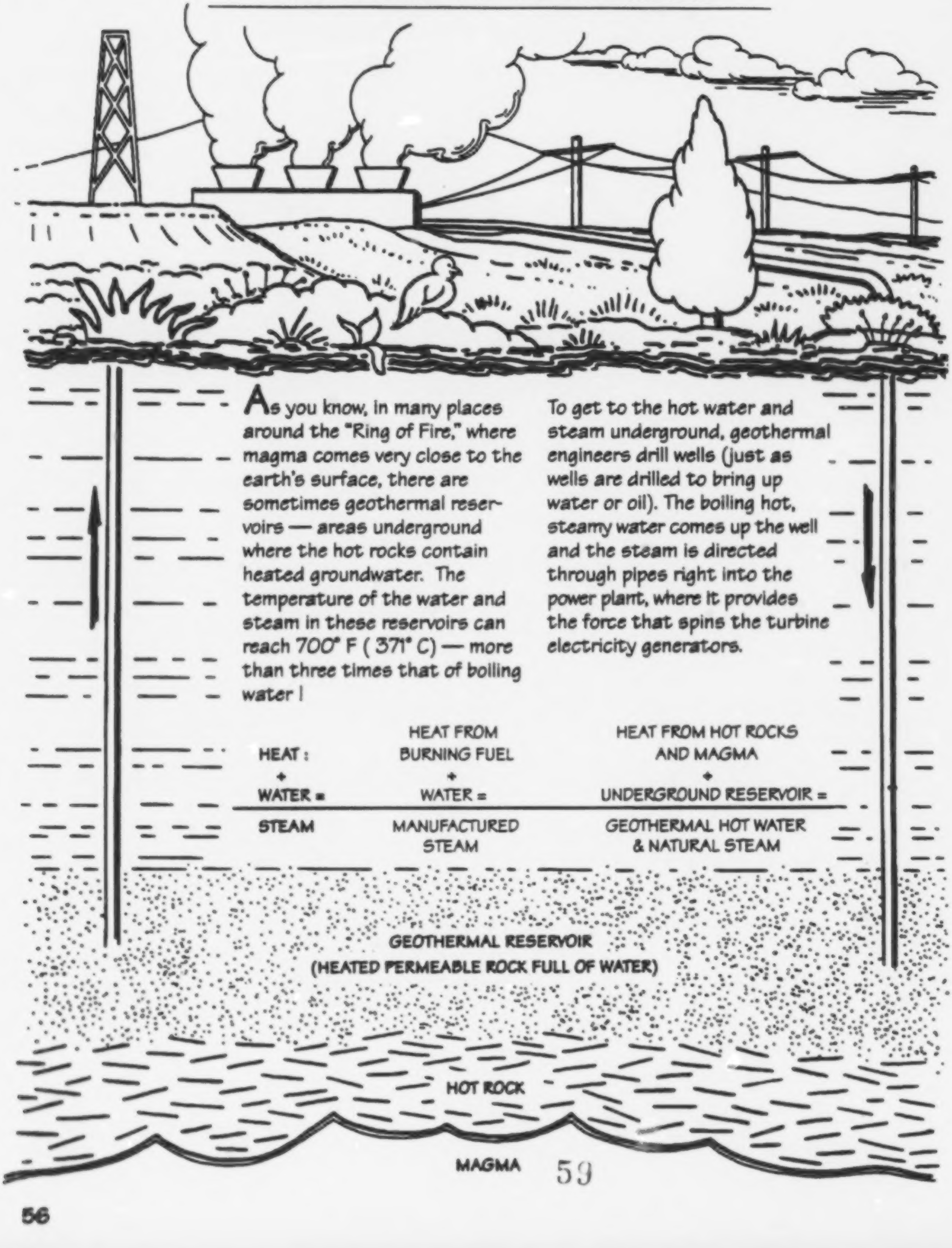


NUCLEAR

BIOMASS

STUDENT INFORMATION

GENERATING ELECTRICITY WITH NATURAL STEAM AND HEAT FROM GEOTHERMAL RESOURCES

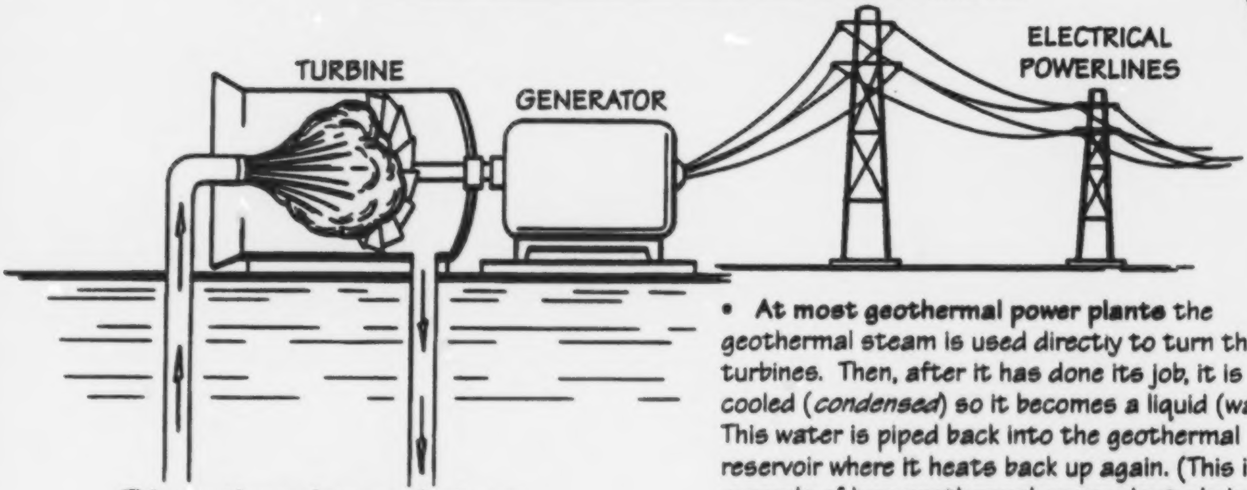


As you know, in many places around the "Ring of Fire," where magma comes very close to the earth's surface, there are sometimes geothermal reservoirs — areas underground where the hot rocks contain heated groundwater. The temperature of the water and steam in these reservoirs can reach 700° F (371° C) — more than three times that of boiling water !

To get to the hot water and steam underground, geothermal engineers drill wells (just as wells are drilled to bring up water or oil). The boiling hot, steamy water comes up the well and the steam is directed through pipes right into the power plant, where it provides the force that spins the turbine electricity generators.

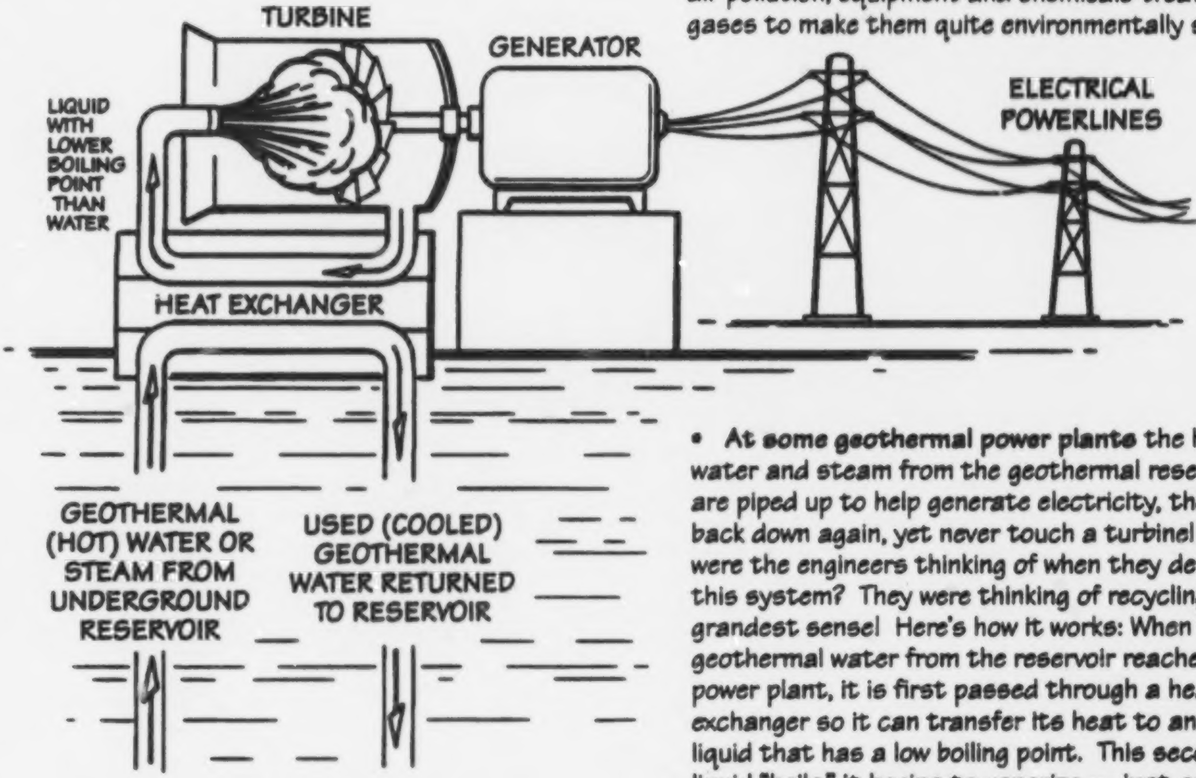
HEAT :	HEAT FROM BURNING FUEL	HEAT FROM HOT ROCKS AND MAGMA
+	+	+
WATER =	WATER =	UNDERGROUND RESERVOIR =
STEAM	MANUFACTURED STEAM	GEOTHERMAL HOT WATER & NATURAL STEAM

GEOTHERMAL POWER PLANTS


TURBINE
GENERATOR
ELECTRICAL POWERLINES

This geothermal power plant uses geothermal steam to turn a turbine.

- **At most geothermal power plants** the geothermal steam is used directly to turn the turbines. Then, after it has done its job, it is cooled (*condensed*) so it becomes a liquid (water). This water is piped back into the geothermal reservoir where it heats back up again. (This is an example of how geothermal power plants help "recycle" and renew the geothermal resource.) Some gases (mostly carbon dioxide) are contained in geothermal steam. Because of concerns about air pollution, equipment and chemicals treat these gases to make them quite environmentally safe.


TURBINE
GENERATOR
ELECTRICAL POWERLINES
LIQUID WITH LOWER BOILING POINT THAN WATER
HEAT EXCHANGER
GEOTHERMAL (HOT) WATER OR STEAM FROM UNDERGROUND RESERVOIR
USED (COOLED) GEOTHERMAL WATER RETURNED TO RESERVOIR

This geothermal power plant uses geothermal water with a heat exchanger system to turn a turbine.

- **At some geothermal power plants** the hot water and steam from the geothermal reservoirs are piped up to help generate electricity, then piped back down again, yet never touch a turbine! What were the engineers thinking of when they designed this system? They were thinking of recycling in its grandest sense! Here's how it works: When the hot geothermal water from the reservoir reaches the power plant, it is first passed through a heat exchanger so it can transfer its heat to another liquid that has a low boiling point. This second liquid "boils," it begins to *vaporize* — just as water vaporizes (becomes steam). This new vapor is then used to turn the turbines. The beauty of this system — called binary (bi = 2) because it uses two liquids — is that both the geothermal water and the other liquid recirculate continuously in their separate pipes, so that both are used over and over again and nothing is wasted. Nothing at all goes into the air. This is a 100% clean form of electrical power production.

ALL STEAMED UP: MAKING A MODEL GEOTHERMAL STEAM ENGINE

In this activity, you will be exploring several ideas.

First, you will be demonstrating how steam is used to turn a turbine engine. In order for steam to hit the turbine with enough force to make it move, it must be rushing from its source at high pressure. In this demonstration, you'll notice that the steam is coming through a small hole, which forces the steam to come out with the greater force needed to move the turbine blades.

Second, you will be creating a visual demonstration of energy conversion. Remember that energy comes in different forms and can be converted (changed) from one form to another.

Simply speaking, in this activity heat energy is converted into mechanical energy. The same is true in a geothermal power plant.

The next step at the geothermal plant would be to convert the mechanical energy of the moving turbine into electrical energy using the generator.

The Geothermal Education Office acknowledges this contribution of the National Energy Foundation.

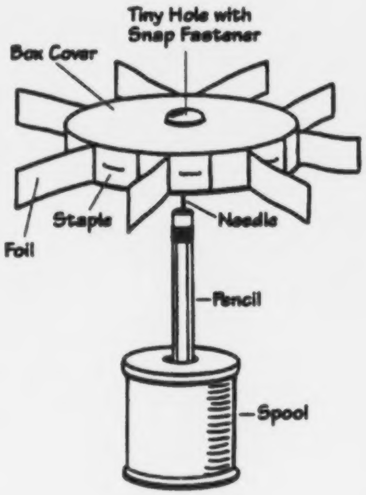
Materials:

Per student group:

- cover of a round box such as a small cardboard ice cream container
- heavy duty aluminum foil
- a snap fastener (the kind without a hole in the middle)
- a needle
- a pencil with eraser
- an empty thread spool

For all groups:

- a stapler
- a tea kettle or pot with lid
- a stove or burner
- an oven mitt
- kitchen or barbeque tongs
- cellophane tape
- water
- ruler
- scissors



Directions:

1.) Cut the foil into eight pieces each 7.5 cm long and 5 cm wide. Fold each piece in half.

2.) Staple and/or tape each piece to the box cover.

3.) Push the end of the needle (the "eye" end) into the eraser of the pencil. Be careful of the pointed end sticking up.

4.) Put the box cover on the point of the needle. Work with this until the box cover hangs straight and even. Make a tiny hole at this balance point.

5.) Push the bottom half of the snap fastener into this hole.

6.) Put the point of the pencil into the hole in the spool.

7.) Rest the box cover with snap fastener on the point of the needle.

8.) Boil water in the kettle or pot with lid (place the lid slightly off center so that the steam will push out strongly from one side).

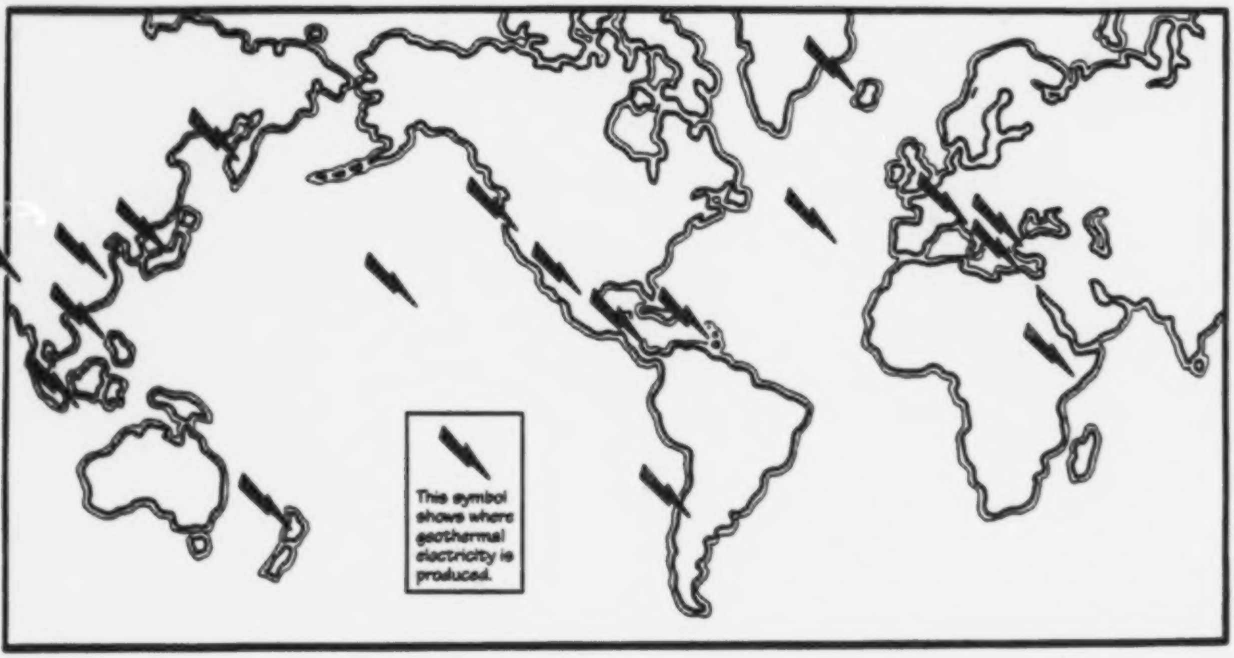
9.) Wearing the oven mitt, hold the device with the tongs near the steam coming out from the kettle (or gap in pot + lid). Observe what happens.

10.) Be ready to discuss where the wheel gets its power to turn and how this relates to geothermal power plants.

GEOTHERMAL ELECTRICITY TODAY

The geothermal energy industry is a growing electricity producer. 5,700 megawatts of "geothermal electricity" (the equivalent of over a hundred million barrels of oil per year) are "current"ly being produced in many countries around the world — mostly in Italy, New Zealand, the Philippines, Japan, Indonesia, Central America, Mexico, and the western United States. And geologists are doing lots of exciting exploration in many other promising locations so that the geothermal megawatt numbers will soon be on the rise.

In the United States geothermal power plants have the ability to produce over 2,500 megawatts of electricity – enough to meet the electrical needs of more than 3 million households. Using this much geothermal energy saves the equivalent of about 50 million barrels of oil each year.



DID YOU KNOW ?

Geothermal and the Environment

☞ The geothermal water that is used in power plants is always sent back into the geothermal reservoir so that surface water and fresh ground water stay clean and safe to use.

☞ In the U.S. more electricity is produced from geothermal resources than from wind and solar combined.

☞ *Geothermal power plants give off very few pollutants when compared to power plants that use fossil fuels.* In fact, binary power plants give off no carbon dioxide, sulfur oxides, or nitrous oxides – the main "bad guys" in the showdown between clean air and pollution.

☞ The world's largest geothermal electric power plant development is found in Lake County, CA. In 1991, this county became the first and only county to meet all of California's really tough air quality regulations.

☞ It takes less land to produce electricity from geothermal resources than from almost all other energy resources.

BEST COPY AVAILABLE

GEOTHERMAL TOMORROW

Improvements in geothermal technology and engineering techniques will soon allow us to use geothermal energy even more in the future than it is today. Possibilities already being explored involve using the heat directly from hot "dry" rocks and magma — without the need for a natural geothermal reservoir. Both of these methods involve piping water down into these very hot underground areas so it can heat up. The result — even more geothermally heated hot water and steam will be available to turn turbines in power plants around the world.

Thar's heat in them thar hills!

IT'S "POWER"FUL

Long ago, in the first century AD, some inventive Greeks attached paddles to a long stick and placed it into a stream of running water. As the water hit the paddles, the center stick turned and thus one of the first waterwheels was invented. Since that time, waterwheels and their cousins, the turbines, have been put to work in many ways, eventually ending up in enormous turbine electricity generators that produce the electricity we so casually use everyday.

For centuries, human beings have been discovering ways to harness the forces of the natural world in order to improve or change their lives. From the discovery of the many uses of simple machines such as the lever and the knowledge of fire's potential to the era of the microchip, women and men have been discovering and rethinking new uses of power. With each discovery, or "reinvention," life changed somehow. People generally thought each change was for the better. Now, in retrospect, some changes may not be viewed to be as beneficial as people originally thought.

We may take for granted some of the discoveries that led us to where we are today. Some research into the history of power may allow us to recapture a sense of wonder about the natural world and and how we use its "power"ful forces.

Suggested Activities:

1.) Pick a topic and select a variety of resources for information.

Suggested Topics
(pick any others of your own):

- the use of fire
- inventions developed by ancient civilizations (such as Egyptian, Phoenician, Greek and Roman)
- the Industrial Revolution
- the use of water wheels during the California Gold Rush
- Thomas Edison
- James Watt
- Allesandro Volta
- Andre Marie Ampere
- uses of power sources in transportation
- the atomic age and nuclear reactors
- the mining industry around the world

2.) Find out all about your topic. Be sure to ask who, what, when, where, and how.

3.) If possible, make sketches (illustrations and/or diagrams) of the subject of your topic.

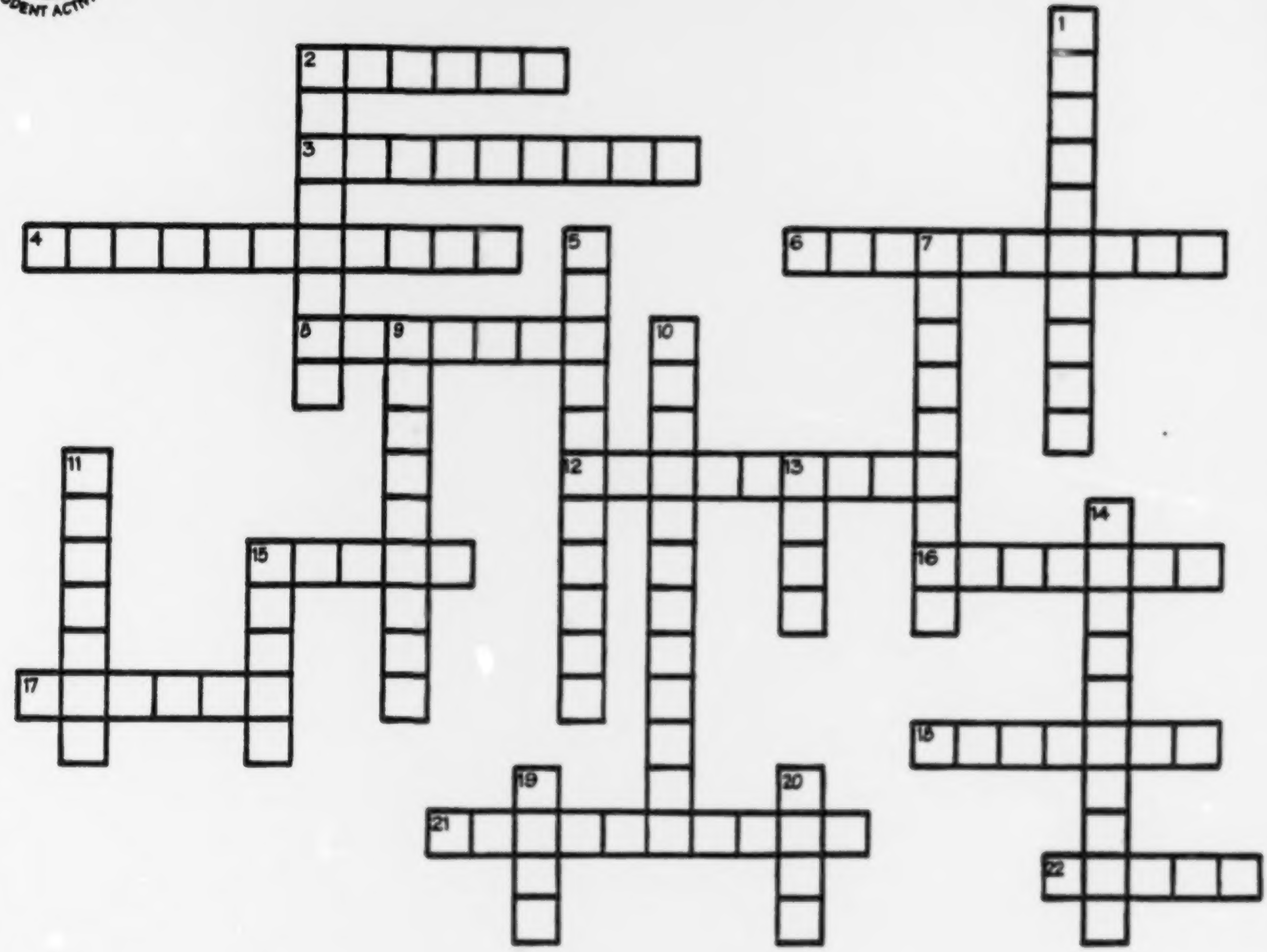
4.) What creative processes and/or series of events lead to the discovery, invention, or development of your topic?

5.) Discuss whether your topic was considered to improve life at the time it was developed.

6.) Discuss whether you considered the use of your topic to really be an improvement. Conversely, do you think we'd be better off without it? Be sure to give your reasons why.

7.) Besides improvement of life, what other motivation may have been involved in the development of your topic? (Consider: greed, power, desire to help others, "the need to know" and so forth).

POWER PUZZLE



ACROSS — ELECTRIFYING PUZZLE CLUES — DOWN

ACROSS

2 a material that "attracts" certain metals
3 uses magnets and coiled wires
4 water that has collected under the earth's surface
6 central station for electricity production
8 a machine with turning blades used in making electricity
12 an underground area of hot permeable rock full of water
15 coming from the sun
16 a form of power that comes from "splitting" atoms
17 country which began using windmills around the 10th century A.D.
18 a continuous flow of electrons
21 ancient capital, home to great library
22 "hydro" means ____________

DOWN

1 fuel from ancient living things, such as coal
2 one million watts
5 the energy of moving electrons
7 tiny particles; part of an atom
10 using resources wisely
11 fuel from living things
13 in electricity: measurement of the amount of "push" electrons are getting
14 heat from the earth
15 heated water vapor
19 a form of energy that can warm our homes
20 __________ drives windmills to produce power

POWER PUZZLE WORD BANK

Alexandria
biofuel
conservation
current
electricity
electrons
fossil fuel
generator
geothermal
groundwater
heat
magnet
megawatt
nuclear
Persia
powerplant
renewable
reservoir
solar
steam
turbine
volt
water
wind

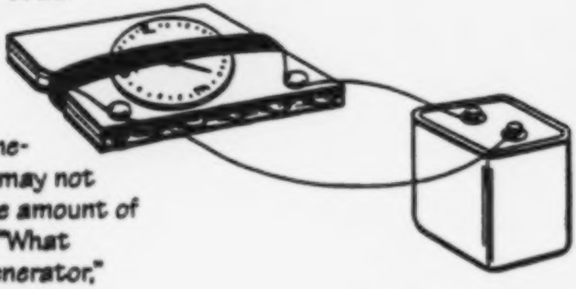
Science Activity: What Happens Inside a Generator
(student worksheet included)

Materials: Per student group
- strong bar magnet with "poles"
- enough insulated copper bell wire to make a fifty-loop coil larger than your magnet
- current detector (galvanometer)

Management suggestions:
The magnetic field of the magnet will cause movements of the electrons in the wire, generating electricity. Students should see that it doesn't matter whether the coil or the magnet is moving. If the galvanometer doesn't react, try making more wire coils, or try a stronger magnet. Also, some current detectors are better than others. You may want to check with your local electronics store if your detector doesn't work. You may also wish to try making your own galvanometer. A suggestion for making one follows.

Science Activity: Building a Galvanometer (Current Detector)
(no student worksheet)

You may wish to demonstrate to your students how a galvanometer works. This could coordinate with the previous student activity, "What Happens Inside a Generator." This homemade galvanometer may not be able to detect the amount of current produced in "What Happens Inside a Generator," but you might try it and see.



Materials:
- small compass
- clear tape
- heavy cardboard
- fine, insulated, copper bell wire
- brass paper fasteners
- large lantern battery

Directions:
1.) Cut a small platform out of the cardboard and fasten the compass to it with tape (see picture). Cut two slots at the North and South markings on the compass.
2.) Wind about fifty turns of the wire through the slots and around the compass and cardboard (see picture). Leave about two feet (60 cm) of wire free at each end.
3.) Put two paper fasteners through the cardboard and twist the free ends of the wire around them once or twice. Scrape (or strip) away about an inch of insulation from each of the free ends.
4.) Have students watch as you attach the exposed ends to the terminals of the battery. The needle of the compass should move, indicating that electricity is flowing. Because electricity creates a magnetic field, the compass detects it. This instrument is a "galvanometer" and is used to detect current.
5.) Have students watch as you reverse the wires so they touch the opposite terminals. They will see that the needle moves in the other direction. This is called "reversing the polarity." Students will see that the electric current will flow in either direction.

Science Activity: All Steamed Up
(student worksheet included)

Materials: Per student Group:
- cover of a round box such as small cardboard ice cream container
- heavy duty aluminum foil
- a snap fastener (the kind without a hole in the middle)
- needle
- pencil with eraser
- an empty thread spool

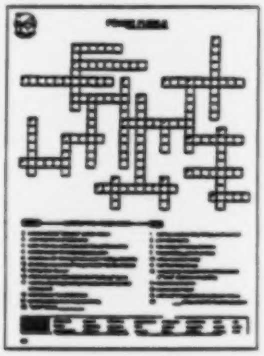
For All Groups:
- stapler, ruler, scissors
- tea kettle or pot with lid
- stove or burner
- an oven mitt
- kitchen or barbecue tongs
- cellophane tape
- water

Directions: Found on student worksheet.

Management suggestions:
Caution all students about the dangers of working around heat and steam. You may want to provide direct supervision with younger students while they work around the steam.

FOR THE TEACHER, cont.

Social Studies/Language Arts Activity: It's Powerful
No management suggestions.



Student Activity Page: Power Crossword Puzzle

ANSWERS

Across:
2. magnet 3. generator
4. groundwater 6. powerplant
8. turbine 12. reservoir
15. solar 16. nuclear
17. Persia 18. current
21. Alexandria 22. water

Down:
1. fossil fuel 2. megawatt
5. electricity 7. electrons
9. renewable 10. conservation
11. biofuel 13. volt
14. geothermal 15. steam
19. heat 20. wind

Math/ Social Studies Activity: "How Much Do You Use?
(no student worksheet)

Discuss how electric power companies know how much electricity is being used in a home by explaining the following: when your family pays for your electricity bills, you are paying for the quantity of energy delivered during a specific time period. This energy is sold in units called kilowatt-hours (a kilowatt-hour tells you how much electricity is being used). A device called a meter records the energy used by all the electric circuits in your home. You can read your own meter. Get someone to show you where the meter is outside your home. The meter has 4 or 5 dials – depending on how old it is. Newer meters have five dials.. The dials record kilowatt-hours in units of 100,000, 10,000, 1,000, 100 and 10. When the pointer is between two numbers , read the lower number. If it is between 0 and 9, read it as 9 because the zero is really a 10. If it is on 0 or between 0 and 1, read as 0 (the zero is really a 10, but is recorded as a zero).

Have your students do something like the following:
1. Locate your meter at home with the help of an adult. Read your meter and record the reading, the time and the date.
2. The following day, go out at the same time read and record your meter reading.
3. Subtract the previous day's reading from the next day's. The answer will be the amount of electrical energy you used.
4. Bring your data to school and combine it with the readings of the rest of your class. Using these figures, find the average electrical usage for your class.
5. **Bonus:** Call your energy company for information about how much energy various electrical appliances in your home use. Pick out the ones that use the most energy. Think about how you and your family could cut back on energy use. Talk this over at home.

Science Activities: If your students show interest in doing more activities with energy sources such as wind or solar power, you will find many references available that have excellent, fun activities. Some suggestions include:

a.) Construct or purchase a wind vane and anemometer (measures wind speed) and use them to see what the best site would be around your school to set up a wind-powered generator.
b.) Test various windmill propeller shapes and sizes to see which one works best.
c.) Use a solar cell, voltage meter, and mirrors to see which position and how many mirrors produce the greatest amount of electric current.
d.) Use various solar cells and model cars; test to see which combination goes the fastest.
e.) Burn nuts to measure the amount of biomass energy available in plant matter. Several resources have good experiments for this.

Values Clarification: Have student groups research various energy resources (include as many as possible). Then have a "town council" meeting where students act out the roles of various citizen groups who want "their" form of energy resource to be used for a proposed power plant in their community.

FOR THE TEACHER, cont.

Environmental and Civic Concerns

If your class discusses energy resources and how their use affects the environment, you may want to include some of the common concerns regarding each one.

__Biomass__: The energy from biofuels is released by combustion and therefore they have to produce some pollutants. Most biofuels are less polluting than fossil fuels. For example, ethanol and methanol (chemically converted forms of biofuels) produce less carbon monoxide and other pollutants than fossil fuels. Wood typically has no sulfur emissions. Biofuels are renewable and can supplement or replace conventional fuels such as fossil fuels. They are also a way of recycling nature's wastes. However, they won't "catch on" as a replacement for conventional fuels unless it is cost-effective to use them. At present, wood wastes that can be converted into pulp and paper sell for much higher price than they would if used for energy. How cost-effective biomass energy is also depends on the promise of a long-term, nearby and steady source of biofuel material. For example, if a biofuel product has to be transported far or if it is expensive to process, then it won't seem attractive as an alternative to conventional fuel.

__Fossil Fuels__: The use of fossil fuels may result in harmful effects on the environment. These effects are: increased air pollution, *acid rain*, a chance of oil spills, *ground water pollution*, and possible *global warming*. Fossil fuel power plants are now under public and governmental pressure to control their emissions. As we learn to use more conservation and renewable energy sources, we need a "weaning" period away from fossil fuel use. At present the spotlight is on using more natural gas because, of all the fossil fuels, natural gas produces the fewest pollutants.

Another major concern is the tremendous rate at which we are using fossil fuels (a nonrenewable resource). Also, the United States imports a great deal of its oil not only because we consume more than we produce, but because we have depleted much of our original resources. Using renewable energy sources and conserving energy reduces the rate at which we are consuming fossil fuels and decreases our dependence on foreign oil.

__Geothermal:__ Geothermal is a clean and reliable energy resource that isn't being used as widely as it could be. Some of the reasons for this are: **a)** Geothermal resources often occur in forests or uninhabited areas. In these areas, some people object to the "industrial look" of power plants. **b)** Some geothermal resources are found in "protected" areas and cannot be developed. **c)** We can only use geothermal where we find it. Steam cannot be transported long distances, as can coal or oil. **d)** Because fossil fuels can be transported to a noncontroversial plant site, investors often find them more appealing. **e)** As with fossil fuels, drilling for geothermal resources can be costly and time-consuming. **f)** Some geothermal sites can produce polluting gases - though far fewer than those asociated with fossil fuels - about 1/1000 of the pollution produced by coal plants, for example. Geothermal power plants produce a fraction of the carbon dioxide and sulfur dioxide associated with fossil fuel power plants. In the past, geothermal power plants did produce some hydrogen sulfide, which is now almost completely removed with modern scrubber systems.

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FOR THE TEACHER, cont.

Nuclear: Nuclear reactors don't cause the kind of air pollution that would come from a fossil fuel plant because nothing is burned. Nuclear fuel and nuclear reactions, however, emit harmful *radiation* that has to be carefully contained. Nuclear plants also have to ensure against an uncontrolled nuclear reaction which could cause great damage and release radiation. The biggest concern is the disposal of nuclear waste (left over after producing and using nuclear fuels). Nuclear waste gives off radiation for up to thousands of years before it is considered "safe." At present, there is a great deal of public concern regarding the safety of nuclear waste production and disposal.

Solar: Solar photovoltaic plants use rows and rows of huge solar cells which convert larger amounts of the sun's energy into electricity. At present, the wider-spread usage of these "sun farms" is affected by high cost, the need for direct and steady sunlight, and the amount of space required. Solar thermal plants also need a large supply of sunlight and quite a sizable amount of space. Also, as with wind farms, solar farms may not be considered an attractive addition to an otherwise beautiful landscape. Engineers are working on ways to reduce the cost and size of solar farms so that we can make greater use of the plentiful energy provided by the sun. Some individual homes far from power lines already get much of their energy from the sun.

Water: Hydropower is considered a relatively clean and economical energy source. However, hydroelectric power plants can cause great changes in the environment of the area in which they are located, because free-flowing rivers are dammed. This can affect the local plants, fish and other wildlife, recreation, and sometimes even other local industries. The use of hydroelectric power plants is not expected to increase much in the near future because there are very few possible sites left in the United States that can be developed. The Northwest has many hydroelectric plants with most of the sites already being used. For those remaining sites, the biggest concern is how development would affect endangered fish runs.

Tidal energy isn't very common because it is restricted by location, the harshness of tidal forces, and high costs. However, some energy experts see promise for the use of tidal power in the future.

Wind: Windpower is a clean, safe energy resource. Because the wind only blows at certain times, wind farms must be situated in locations which have frequent steady winds. For example, Oahu, Hawaii, with its steady trade winds, was home to wind farms which could have provided for 10 percent of Hawaii's energy needs. Even though wind energy is no longer being used to generate power in Hawaii, it is still considered an imporant part of Hawaii's energy plan. More than 16,000 wind turbines in California are generating 2.7 billion kilowatt hours of electricity every year. Researchers are trying to find ways to make wind electricity generators even more useful, such as improving methods to store energy for use when the wind doesn't blow.

Another issue is that some people see windfarms as artistic additions to the landscape, but others consider a large windfarm to be unsightly and, at times, noisy. This concern is addressed by locating windfarms far from residential and scenic areas. Finally, effects on bird populations are carefully monitored to make sure few accidents between birds and blades occur.

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A GEOTHERMAL SCRAPBOOK: HOT ITEMS

SECTION V

Another Hot Resource

Earth Heat

Many know about hot springs, geysers and volcanoes — all evidence of the tremendous heat that lies within the earth. However, many don't know that there is another not-so-dramatic heat energy resource — earth heat. With its huge mass and insulating properties, the earth maintains a constant temperature just a few feet below the surface. We can take advantage of these stable temperatures by installing a simple system called a geothermal – or "ground source" – heat pump. Even where other forms of geothermal energy aren't readily available, geothermal heat pumps (GHP's) can be used to heat homes and buildings.

Used all over northern Europe for many years, GHP's are a relatively new technology in the United States – in commercial use only since about 1980. Like other types of heat pumps (such as "air-source" and "water-source") ***GHP's move heat instead of making heat.***

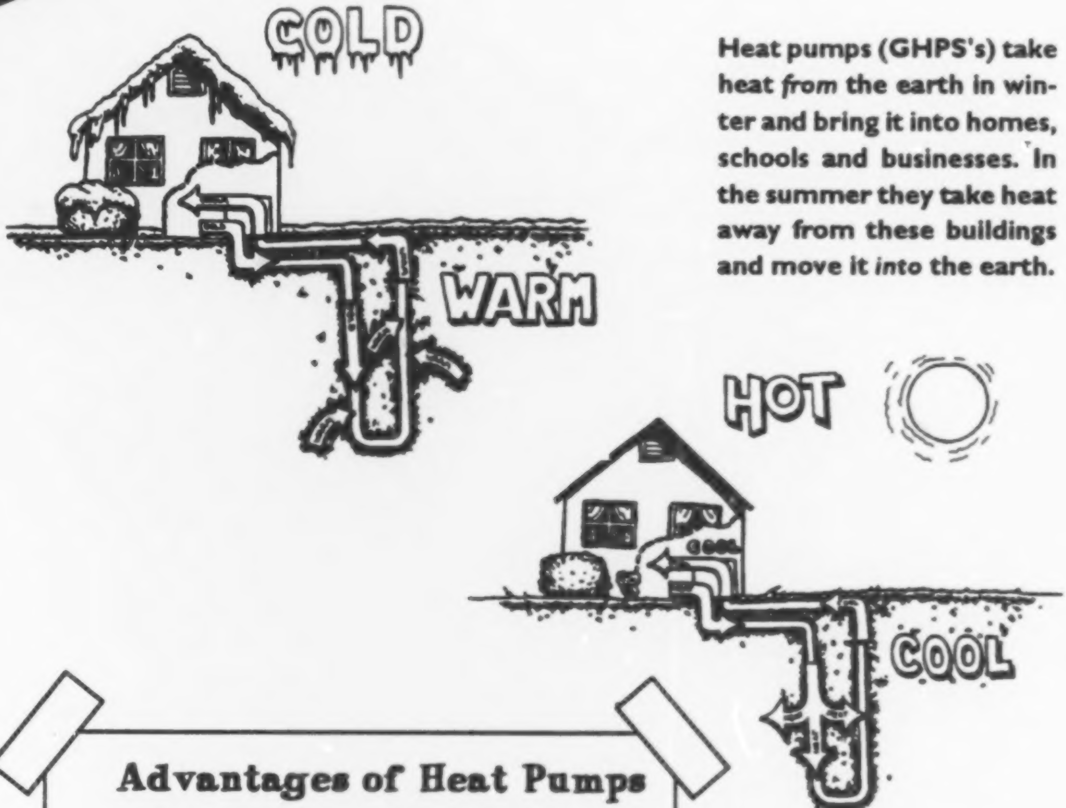
Starting at just about four feet below the surface, the earth's temperature is around 52 degrees Fahrenheit. In order to make use of this constant temperature, water is circulated through many yards of looped pipe, installed (either vertically or horizontally) underground. If a building is being *heated*, the water circulating in the pipe absorbs heat from the earth (due to heat flow). This "captured" earth heat is then "boosted" to a higher temperature, using a heat exchanger. Then the heat is circulated through the building.

By reversing the action of the heat exchanger, earth heat can be used to cool buildings, too. To *cool* a building, the heat pump shifts heat *out* of it. The water circulating in the pipes is warmed by hot summer air, then carried underground where the heat from it flows into the earth, and the same water, *now cooler*, returns to the building, where it captures more heat and takes it away.

Because GHP's don't generate much pollution (they do use a little electricity to move the heat around) and are very energy efficient, they are on the list of preferred technologies selected by the Environmental Protection Agency.

The United States Department of Energy, the EPA, the Geothermal Resources Council, the Geo-Heat Center and others are all looking very closely at GHP's as an important new technology for helping to meet the energy needs of today and tomorrow. How about you?

HOT RESOURCES



Heat pumps (GHPS's) take heat *from* the earth in winter and bring it into homes, schools and businesses. In the summer they take heat away from these buildings and move it *into* the earth.

Graphics courtesy of Oklahoma State University

Advantages of Heat Pumps

- Though initial costs are higher than traditional systems, consumers can save from $200-$800 per year or more (depending on home size) on energy bills, thus recovering their investment and saving a great deal of money on future energy costs.
- Because of their high efficiency, GHP's save large amounts of electricity and natural gas when compared to other heating/cooling systems.
- Their simple design makes the maintenance of GHP's easier than traditional systems.
- Because the loops are underground, outdoor landscape is rarely affected.
- Local contractors can do most of the work, so the GHP business is attractive for local economies.
- It has been estimated that over one-half of the United States has places suitable for GHP installation.

HOT CAREERS

Is There a Job For You in Geothermal?

People like to work in the geothermal industry. It gives them satisfaction to produce heat and electricity which improve people's lives without hurting the earth and the air. The search for geothermal resources and the development of geothermal energy is challenging and open to innovation.

Geologists search for geothermal heat near the earth's surface. Geochemists, geophysicists, hydrologists and other specialists help in the search. If a geothermal reservoir is found, then land ownership permitting and leasing specialists obtain rights for exploration and development. Project managers and drilling engineers work with geologists to plan a drilling program to find the resource.

A successful well requires the cooperation of many special workers — tool pushers, mud loggers, pipefitters, cement truckers and water truckers. If the temperature of the resource is low, fish farmers and greenhouse growers use it to grow fish, vegetables or flowers. Architects, builders and heating experts plan and construct houses and commercial buildings heated by low-temperature geothermal waters. If the temperature is high enough to make electricity, then other workers are needed.

Geologists and reservoir engineers plan where to drill for steam and hot water. Electrical and mechanical engineers and construction workers design and build power plants to turn steam into electricity. City planners and power line operators work with utilities and governments to plan how to move the electricity to people.

Before the power plant and power lines are constructed, expert wildlife biologists, botanists, soil scientists, archaeologists, hydrologists, air quality scientists, chemists, engineers, and noise specialists prepare environmental impact studies which are needed to safeguard nature during development. Power plant operators, financial experts, accountants and bookkeepers, corporate attorneys, public relations professionals, government regulatory experts, administrative assistants, and receptionists also play their part.

Geothermal is a young, developing industry. Researchers in private and government institutions work on technology improvements. All of these people work in the geothermal industry to keep power turbines rolling and clean heat and electricity coming to you and me.

Adapted from the *Steam Press*, Spring 1992

It's Time For An Oil Change!

Renewable energy resources can play a major role in our quest for independence from foreign oil.

Recent events underscore, once again, the fact that we can no longer rely on imported oil. Some twenty years ago, when oil prices skyrocketed, service stations across America were besieged by gas lines, the sale of locking gas caps soared and gas rationing loomed as a real possibility. It seems that we did not learn our lesson from that experience. As that crisis eased, we went right back to the old ways, with no plans or energy programs for such future catastrophes. As a result, we became even more dependent on oil. Imported oil now accounts for approximately 50% of our current fuel needs, compared with less than 30% in 1985. And now we have another problem and an added financial burden — the astronomical costs of protecting these foreign oil resources.We know too that, compounding the problem, the burning of oil and other fossil fuels is doing irreparable damage to our environment. Carbon dioxide emissions, the "greenhouse" effect and global warming are now household words. How can we help reverse the damage and put the U.S. back on the road to energy independence? We must begin immediately an aggressive program to initiate more energy conservation programs and to develop our renewable energy sources. The true potential of geothermal, solar, wind and other alternative energy reserves within the U.S. is enormous. They are proven resources that, in many cases, cost substantially less than oil, coal and natural gas. But perhaps the biggest incentive for us to focus our energy on these renewable energy sources is the very future of our planet itself.

(Adapted from the *Steam Press*, Fall 1990)

Geothermal's HOT HISTORY

Early History

3500 years ago Mineral springs used by ancient Romans for bathing, cooking and heating. Hot springs also used by the Chinese, Japanese and later by native Americans.

2000 years ago Geothermal waters used to treat eye and skin diseases throughout the Mediterranean.

1000 years ago Yellow sulfur for salves, gunpowder, disinfectants, and other uses produced from geothermal salts.

1800's

1890 Production of boric acid for medicinal purposes from geothermal springs.

1891 First U.S. district heating from geothermal implemented in Boise, Idaho.

Early-Mid 1900's

1900 Geothermally-heated water provided to homes in Klamath Falls, Oregon.

1904 Electricity generated from Earth's natural steam, Larderello, Italy.

1930's Geothermal water now commonly used in the U.S., Iceland, Japan, New Zealand, the Soviet Union and other countries for spas, pools and greenhouses. First use in Iceland for heating of buildings.

1943 132 megawatts produced from geothermal fields in Larderello, Italy.

Late 1900's

1958 New Zealand successfully produced electricity from geothermal using a new method (flash).

1960 First commercial electricity generated from dry steam at The Geysers, California.

1966 First geothermal power plant built in Japan.

1969 France begins large district heating projects with geothermal waters.

1970 First electrical generation from geothermal in China. Exploration for geothermal resources begins in Greece and Guatemala.

1978 First Hot Dry Rock reservoir created and tested by the U.S. Department of Energy in New Mexico. Geothermal crop-drying plant built in Nevada.

1979 First electrical production from geothermal in Indonesia.

1980 World's largest geothermal generator (132 MW) built at The Geysers. Electric power from hot dry rock produced in New Mexico.

1981 Binary technology successfully used in the Imperial Valley, California. First electrical production from geothermal in state of Hawaii.

1982 Total U.S. installed geothermal capacity reaches 1000 MW.

1984 First electrical production from geothermal in Utah.

1985 U.S. installed geothermal capacity reaches 2000 MW. 2 MW electrical generation begins in Greece.

1989 First exploratory well to be sited directly over a body of magma by U.S. Department of Energy.

1990 Three U.S. geothermal projects win environmental awards. U.S. installed geothermal capacity reaches almost 3000 MW. New Zealand has about 300 MW of geothermal power plants. 700 MW are being produced in Mexico. 558 MW are being produced in the Philippines. Iceland has drilled, since about 1928, 110 wells for electrical production and 705 wells for direct use.

1991 Bonneville Power Administration selects three sites in the Pacific Northwest for demonstration geothermal projects.

1992 Nearly 6,000 MW of electricity being generated from geothermal in 21 countries.

1993 23 MW binary power plant completed at Steamboat Springs, Nevada. A 50 MW flash steam power plant completed at Los Azufres Geothermal Field in Michoacan, Mexico by Comision Federal de Electricidad (Mexico's state utility).

1994 Acceptance of the Environmental Impact Statement for the Newberry Pilot Project, allowing the first geothermal power plant in Oregon. Costa Rica becomes a geothermal country with the completion of a 50 MW flash steam power plant at Miravalles Geothermal Field.

Tomorrow

The amount of electricity being produced from hydrothermal resources will certainly continue to grow. Scientists from the U.S. Department of Energy are working hard to find ways to access and use the earth's heat at very deep levels — up to 10 miles! This research is focused on magma and hot dry rock.

By the year 2030, generation of electricity from geothermal sources is projected to grow to 10,600 MW. That's enough electricity to serve 10.5 million households.

The value of low temperature geothermal resources will continue to be researched and will be more widely used.

(Adapted from the *Steam Press*, Spring 1992)

HOT LUNCH

Let Mother Nature Do the Cooking!

Geothermal energy sizzles supper

Adapted with permission from Reuters

When the villagers of Furnas (in the Azores) bury food in the ground around their local volcano, they know a piping hot meal will be ready in a few hours.

"This is what I call down-to-earth cooking," says Fernando Moniz Cabral, as he and another man heave huge pots of cozido, a spicy stew of chicken, sausages, pork and vegetables, from holes in the earth.

Faces red from the effort and heat, they emerge between billows of steam and pools boiling away in the green landscape of tropical flowers, palm trees and lagoons.

For centuries these villagers on the Azores island of Sao Miguel in the mid-Atlantic have harnessed volcanic (geothermal) energy to bake anything from cod to cabbage. The volcanic island, like others in the nine-island Portuguese archipelago, lies on a thin layer of the earth's crust.

During weekends, the site is filled with picnicking families who drop sacks of meat, yams, potatoes and even cornbread into the three-foot deep holes for a couple of hours while they swim at the nearby crater lake. Barefoot boys sitting by the roadside sell husks of "cooked" sweet corn.

With a heat of about 200° Fahrenheit, connoisseurs recommend burying fish for about two hours and meat for up to five. Food is wrapped in paper or cabbage leaves, pots tightly sealed and earth put over the holes to trap the vapor.

Signs spell out the rules: "Cooking corn is not permitted here." "Do not wash clothes." "Using detergent is not allowed." Down the road, tourists stay at a nearby 19th century spa where spring water enriched with minerals pours from rocks laced with purple flowers. And, just a few miles away, engineers are trying to tap the volcanic heat to generate electricity and end dependency on imported fuel.

(Adapted from the *Steam Press*, Spring 1992)

Drawing by Nikki Nemzer

Just Add Water!

Everywhere in the world there's lots of hot rock very deep down in the Earth's crust. Most of it is more than ten miles deep, but in some places it's close enough to the surface for water to trickle down, get all steamed up and create hot underground reservoirs and geothermal systems with hot springs, fumaroles and geysers. We take heat from this hot wet (hydrothermal) rock to make electricity and to heat all sorts of things.

But most of the hot rock doesn't have water trickling into it. Most is Hot *Dry* Rock (nickname HDR), the technical name for this kind of geothermal resource. Scientists from the U.S. Department of Energy - along with researchers from Japan, England, France and Germany - have found a way to *add* the water. In areas where the hot dry rock isn't too deep (up to three and a half miles), engineers drill two parallel wells about 10 inches in diameter. Then they pump water, under pressure, through one of the wells. This pressurized water fractures the rock and opens up natural cracks in the rock at the base of the two wells to connect them. After the rock fractures have been opened, the engineers run cool water down one of the wells to the hot dry rock.

You can guess what happens next! The cool water runs through the large cracks in the hot dry rock and - *voila!* The water gets hot! *Muy caliente! Molto caldo! Totemo atsui!* The Hot Dry Rock system creates (with a little help) its own hydrothermal resource!

Then, of course, the hot water (up to 300 degrees C) comes up the second well, providing the precious clean energy that will be needed to turn the turbines in the power plant above. One of the best things about Hot Dry Rock technology is that when the heated water has done its job at the surface, it is sent right back down again through the well to the hot dry rock underground. And around and around it goes!

In future years, drilling technology will improve, allowing us to drill deeper and deeper, making geothermal energy from Hot Dry Rock potentially available everywhere!

In geothermal energy circles, being "all wet" is a real advantage.

(Adapted from the *Steam Press*, Spring 1993)

CURRENT TOPIC: MIGHTY MAGMA

The United States Department of Energy has some exciting things happening at Mammoth Lakes, California, where long-term research is underway to see if we can use magma to produce electricity: magma's heat might be able to be conveyed through fluid in pipes to make steam to power turbine-generators. Magma is a huge potential resource. Would you believe that the amount of energy that may be available from magma is greater than all oil, coal and gas resources put together? The big question is, "Is it available at shallow enough depths to make it useful to mankind?" Researchers and scientists from the Department of Energy think the answer is "yes." That would be a lot of electricity! Experimental drilling, planned to be four miles deep, has begun in Long Valley Caldera, which was formed over 700,000 years ago from a volcanic eruption over 1,000 times more powerful than the recent Mt. St. Helens eruption! It is a good place for magma research because it is still very geologically active. Maybe someday electricity will be produced from mighty magma! How clean our air would be!

(Adapted from the *Steam Press*, Fall 1990)

HOT WATER

Reno Hotel Has Its Own Geothermal System For Heat

The Peppermill Hotel and Casino has had its very own low temperature geothermal well right in its backyard for over thirty years. The geothermal resource is used to directly heat water for bathing, laundry and heating. The hotel has over 600 rooms, so that is a lot of hot water. In fact, they plan to sell their extra hot water to the car wash across the road and to other nearby businesses. The Peppermill Hotel's well is a "double jackpot winner" — free hot water and good for the environment too!

(Reprinted from the *Steam Press*, Fall 1990)

THE HOT SEAT

Geothermal Energy Questions & Answers

Q. If geothermal is so great, why don't we use it to make all our electricity?

A. We would if we could. Not all geothermal resources are hot enough to produce electricity. Also, some of the "hot enough" resources aren't accessible for use with present-day technology. (The U.S. Department of Energy is doing research to improve technology so we will be able to use more of our geothermal resources.) And "low" temperature geothermal resources are also available for many uses which help us cut down electricity use.

Q. If there is geothermal heat in the earth, why don't my feet get hot?

A. They would if you put them in a hot spring, but in most places, layers of rock, sand and soil protect us from the heat deep inside the earth. Geothermal is everywhere underground, but at a depth safe to our feet.

Q. Will we ever run out of geothermal energy?

A. No. Future generations will always have geothermal energy. Hydrothermal reservoirs contain both water (hydro) and heat (thermal). The heat is always being generated deep in the earth. The water is replenished by rainfall and by returning the used water back into the reservoir.

Q. I have heard that geothermal plants emit carbon dioxide and sulfur gases that contribute to acid rain and global warming. Is it true?

A. It is true that geothermal steam contains sulfur as hydrogen sulfide (H_2S), but the steam is treated to remove almost all of the H_2S. Carbon dioxide (CO_2) is also in geothermal steam, but in comparatively small amounts. A power plant that burns coal to make electricity produces 1700 times as much CO_2 for the same amount of electricity as a geothermal plant. Geothermal energy doesn't flood valleys, cause air pollution, make miners sick or leave radioactive waste. It is a very clean energy technology.

Q. Mexico has a lot of volcanic and earthquake activity. Are they doing anything with geothermal energy?

A. Are they ever! Mexico has more than 130 known geothermal fields, a number of which are already producing geothermal electricity. One of the areas explored, the Cerro Prieto field, is currently producing over 600 MW (much of which is being sold to a utility in the U.S.) and may be able to produce up to 1 million kilowatts of power! Mexico also has many geothermal hot springs which attract thousands of tourists each year.

Q. What else is new in the geothermal industry?

A. Glad you asked! Some geothermal engineers have been inventing portable geothermal power plants! These pre-packaged modular, mobile units have been set up in places which ordinarily wouldn't have electric power, such as the one found in Dieng, Java.

(Adapted from the *Steam Press*, Spring 1992)

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HOT STUFF

TRUE or FALSE

____ 1. Geothermal energy is available practically everywhere, if you just dig down far enough.

____ 2. The first United States geothermal electricity power plant was built in Bakersfield, CA.

____ 3. Greenhouses cannot use geothermal resources.

____ 4. Bathing is a common use of geothermal resources.

____ 5. Islanders on Sao Miguel use geothermal heat for cooking.

____ 6. Use of magma's heat as a geothermal resource has never been explored.

____ 7. Mexico has many known geothermal fields.

MATCHING

__ 1. Coal, oil, natural gas

__ 2. Visible features of geothermal energy

__ 3. A well fitted with a pipe used to carry underground steam to electrical turbines

__ 4. Molten rock

__ 5. Rock heated by magma that is close to the earth's surface

__ 6. A device that turns when steam pushes its blades to generate electricity

__ 7. Stew cooked by geothermal heat in the Azores

A. Magma
B. Fossil fuels
C. Geothermal production well
D. Steam turbine
E. Cozido
F. Volcanoes, hot springs, geysers, and fumaroles
G. Hot Rock

WORD SCRAMBLE

1. RAGMELHOTE

____

2. WEARBEELN YNREEG

____

3. LOGOITEGS

____

4. HSIF ERMARFS

____

5. CLEITECYRIT

____

6. LAGBOL GRINMAW

____

7. REGOFIN LOI

____

FOR THE TEACHER

1. Social Studies/Language Arts Activity: Suggestions using the articles from this section:

- a. Have students pick an article of interest and do further research on the subject.
- b. Ask a group of students to present the information found in the Scrapbook in the form of a TV news broadcast for the rest of the class.
- c. Have students make posters "advertising" information from articles in the Scrapbook.

2. Social Studies Activity: Suggestion for the geothermal time line (Hot History): connect the geothermal history facts with a general historical timeline. Have students make their own timelines, putting in geothermal information and adding in other historical events. Pictures can be added to illustrate key facts or interesting details.

3. Activity Page: "Hot Stuff" Answers:

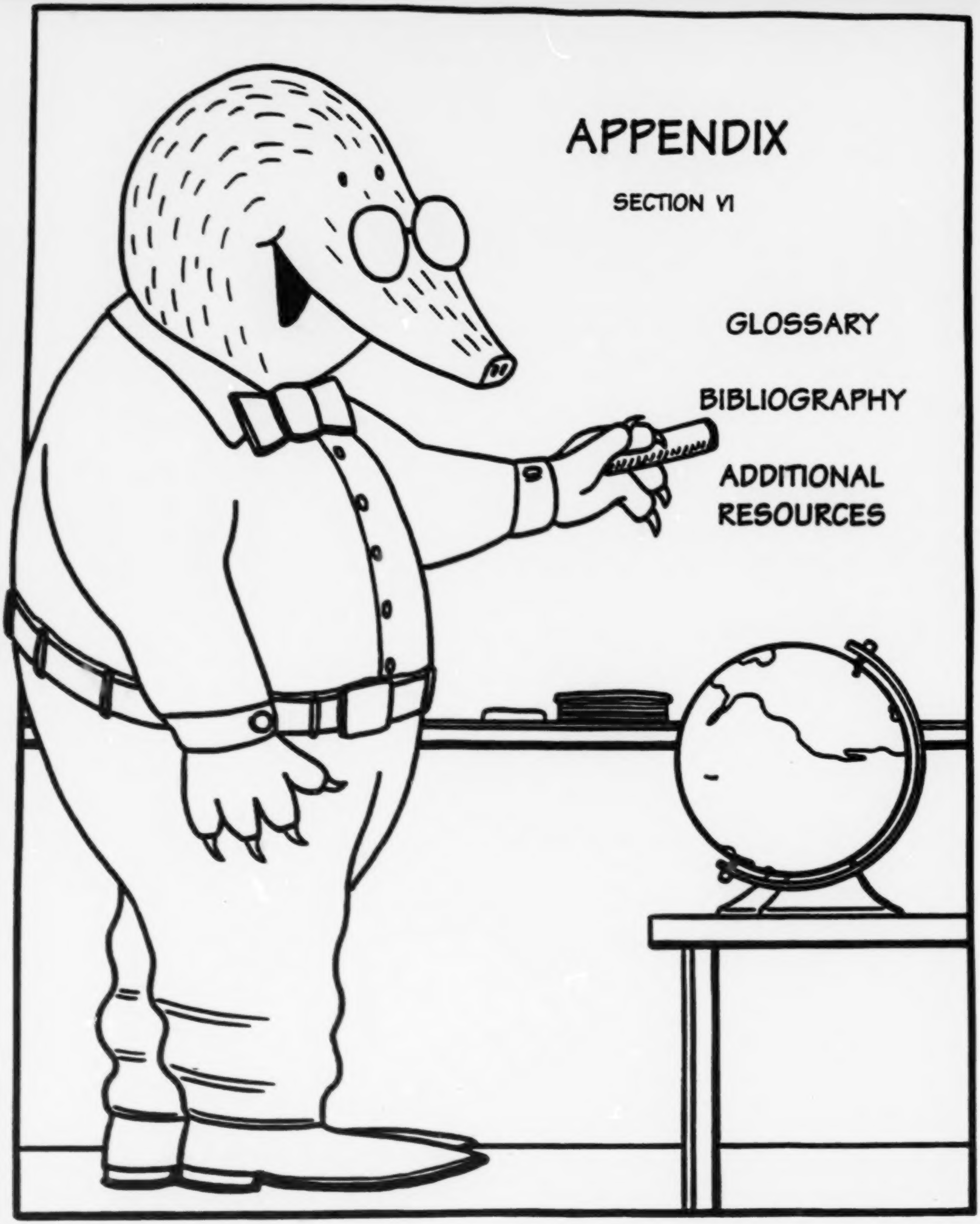
True or False:

1. T 2. F 3. F 4. T 5. T 6. F 7. T

Word Scramble:

1. geothermal 2. renewable energy 3. geologist
4. fish farmers 5. electricity 6. global warming
7. foreign oil

Matching: 1. B 2. F 3. C 4. A 5. G 6. D 7. E



APPENDIX

SECTION VI

GLOSSARY

BIBLIOGRAPHY

ADDITIONAL RESOURCES

GLOSSARY

Section I :

INTRODUCTION

customary measures: a system of measurement based on practices long held by people of the English-speaking world. Utilizes such length measures as inches, feet, yards, miles; volume measures such as ounces, pints, quarts, gallons; weight measures such as ounces and pounds as well as measures for area, capacity and dry measure.

electrical energy: a form of energy in which there is a flow of electrons.

energy: the ability to do work, such as making things move and heating them up. Energy can take many forms, including electrical energy, chemical energy, and heat (thermal) energy.

energy conversion: the changing of one form of energy into another form of energy; one of the many examples is heat energy being converted into mechanical energy.

fuel: something consumed to produce energy; examples include wood, coal, gas, oil, nuclear material, food.

geothermal resource: natural heat, hot water, and steam from within the earth; used to make electrical power and for many other applications such as space heating, agriculture, industry, aquaculture, balneology (spas).

heat (thermal) energy: a form of energy possessed by a material because of the motion of its molecules.

mechanical energy: the energy that moves objects or changes their positions.

metric system: the "international measurement language" of science; a decimal system of measurement units (using multiples of ten) based on the meter as a unit of length, the kilogram as a unit of mass, degrees celsius, as a unit of temperature, as well as measures for area, volume and capacity.

nonrenewable resource: resources that are not replaced or regenerated naturally within a period of time that is useful; this includes fossil fuels and minerals.

renewable resource: a resource that can be used continuously without being used up (because it regenerates itself within a useful amount of time).

Section II :

EARTH'S NATURAL HEAT

carbon dioxide: a gas produced by the burning of such substances as fossil fuels. It is also contained in large amounts in magma, and is involved in the explosive eruption of volcanoes.

continental drift: the theory that the continents as we know them today may have drifted apart when a supercontinent, Pangaea, broke apart into tectonic plates. Continental drift is thought to be caused mostly by convection currents moving in the mantle below the earth's surface.

convection currents: the currents that are caused by hot air or fluid rising. This occurs because the hot air or fluid is lighter (due to expansion) than its cooler surroundings and so it rises; as it cools it becomes heavier and sinks back down.

core (outer and inner): the extremely hot center of the Earth. The outer core is probably liquid rock and is located about 3,200 miles (5,100 kilometers)down from the earth's surface; the inner core may be solid iron and is found at the very center of the earth-about 4,000 miles (6,400 kilometers) down.

crust: the solid outermost layer of the earth, ranging from 5 - 35 miles (8 - 56 kilometers) thick.

GLOSSARY Cont.

density: the amount of mass (weight) in a given volume of something. Two objects can be the same size, but have different densities: one of the objects has more mass "packed" into the same amount of space.

earthquake: the vibration or movement of the ground caused by a sudden shift along faults (cracks) in the earth's crust; most earthquakes occur at the places where tectonic plates are pushing against each other.

eruption: the explosive release of material such as molten rock or hot water (as from volcanoes or geysers).

fracture: a crack or fault in rock.

fumarole: a hole (vent) in the earth's surface, found near volcanic areas, from which steam or gases rise.

geothermal reservoir: a large collection of underground water in layers of permeable rock (trapped between layers of impermeable rock), heated by hot rocks and /or magma.

geyser: a natural hot spring that periodically sends up a fountain of water and steam into the air; some geysers "spout" at regular intervals and some are unpredictable.

groundwater: water that collects underground, mostly from surface water that has seeped down.

hot spring: hot mineral water which bubbles up from below to the earth's surface, and collects in pools, or flows into creeks or lakes.

lava: molten magma that has reached the earth's surface.

magma: hot, thick, molten rock found beneath the earth's surface; formed mainly in the mantle.

mantle: the layer of the earth's interior located between the crust and the core; extending down to a depth of about 1800 miles (2,900 kilometers) from the surface.

molten: made liquid by heat.

Pangaea: the huge supercontinent which scientists believe existed 250 million years ago. All of the continents may have at one time been joined together to make this huge land mass.

permeable: able to be penetrated, especially as by liquids or gasses flowing or spreading through; for example, rock with tiny passageways between holes is permeable.

plate tectonics: the forces or conditions that cause the movement of sections of the earth's crust.

porous: full of small holes (pores).

pressure: the force exerted over a certain area (such as pounds per square foot).

sea floor spreading: the process by which the sea floor is being continuously formed and spread apart, resulting in mid-ocean ridges and tectonic plate movement; caused by magma welling up through breaks in the earth's crust.

subduction: the act of one tectonic plate shoving under another tectonic plate.

tectonic plates: (continental and oceanic): large, slowly moving sections of the earth's crust.

volcano: an opening in the earth's crust from which lava, steam, and/or ashes erupt or flow, either continuously or at intervals.

Section III :

USING EARTH'S "LOW" TEMPERATURE HEAT

agriculture: the growing (farming) of plants, flowers, trees, grains, and other crops.

aquaculture: the raising of fish and other water-dwelling organisms (see aqua farmers).

aqua farmers: farmers who raise freshwater and marine organisms under controlled conditions.

balneology: use of bathing in hot spring mineral water for recreation or medical therapy.

corrode: to eat metals away gradually (such as the rusting of iron).

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GLOSSARY Cont.

cultivate: to grow and tend (plants or crops).

dehydrate: in the case of fruits and vegetables, to remove moisture in order to preserve.

district heating system: a system that provides heat to a large number of buildings all from a central facility.

drying chamber: a box or drum that uses heat to dry (dehydrate) food or other materials.

geothermal water: water warmed by the natural heat inside the earth.

health spa: an establishment (often commercial) which is visited by guests seeking therapy and relaxation; many center around hot mineral springs.

heat exchanger: a device in which heat is conducted, or "flows", (usually through metal) from a hotter liquid or gas, warming a cooler liquid or gas.

injection well: a long vertical pipe through which used geothermal water is returned to an underground geothermal reservoir.

mineralized: contains minerals; for example, mineralized geothermal water contains dissolved minerals from inside the earth.

pasteurize: to use high temperatures to destroy disease-causing bacteria.

therapeutic: the treatment of disease or other disorder; something that may benefit health.

Section IV :

USING GEOTHERMAL ENERGY AT HIGH TEMPERATURES

acid rain: common name for any precipitation (rain, snow, sleet, hail, fog) having a high amount of sulfuric acid and/or nitric acid or having a pH lower than 5.6. Normal rain has a pH of 5.6 - 5.7. Living organisms generally cannot survive if the pH of their environment is too low or too high. Some noticeable effects of acid rain are found in lakes, rivers, and forests, but all parts of an ecosystem are affected by acid rain, even if it isn't readily apparent.

amperes: the measure of the amount of electric current flowing through a wire at a given time.

biomass (biofuel): in the case of electrical production, substances produced by living organisms and used as a source of fuel (bio = life). One of the best examples is wood.

combustion: a rapid chemical reaction releasing energy in the form of heat and light (fire).

condense: to change from a gas to drops of liquid.

electric current: the continuous flow of electrons; often referred to as electricity.

electron: the smallest part of an atom (atoms are the tiny particles of which all substances are made). Electrons may be freed from atoms to produce an electric current.

generator: a machine which transforms mechanical power into electricity.

global warming: the trapping of heat in the atmosphere, also referred to as the greenhouse effect. Incoming solar radiation goes through the atmosphere to the earth's surface, but outgoing radiation (heat) is absorbed by water vapor, carbon dioxide, and ozone in the atmosphere. At certain levels this is beneficial because it keeps the planet warm enough for life as we know it. However, an increase in the normal amount of particles in the atmosphere (such as carbon dioxide) may contribute to a warming trend that may have serious effects on global climate, the global ecosystem, and food supplies.

groundwater pollution: the contamination of water in natural underground reservoirs. Many populated areas depend on these reservoirs for their water supplies.

GLOSSARY Cont.

Library of Alexandria: a great center for learning; located on the Mediterranean coast in the city of Alexandria, Egypt, from about 300 B.C. to 400 A.D. The Library flourished from the period of Greek literature to the Roman and Christian eras. In addition to a huge collection of books, the library was a place for instruction and experimentation.

magnetic field: the area around a magnet throughout which its effects can be measured.

megawatt: one million watts, or 1,000 kilowatts (see *watt,* this section*).*

molecules: extremely tiny particles, composed of a collection of atoms, of which all materials are made .

natural gas: a gas mixture (mostly methane) trapped underground in many places near the surface of the earth; a fossil fuel.

nuclear reactor: a device which splits atoms in a controlled reaction, that results in the release of a huge amount of energy, including heat energy. In a nuclear power plant, the heat from the nuclear reaction is used to make steam to run turbine electricity generators.

photovoltaic cell: an electronic device that converts sunlight directly into electrical energy.

pollution: the presence of substances in water, soil or air in amounts that are harmful to the organisms living in or using the water, soil or air.

power plant: a central station where electricity is produced using turbines and generators.

power transmission lines: wires that transport electricity over long distances.

semiconductor: a material, such as silicon, which can be used to control the flow of electrons in electronic equipment, computers and solar cells.

solar: coming from the sun.

transformer: a device that increases or decreases the voltage of an electric current.

turbine: a machine with blades that are turned by the forceful movement of liquid or gas, (such as air, steam or water) passing quickly over the blades.

vaporize: to change any liquid or solid into the gas form; the term is most commonly used in reference to water (which vaporizes to steam).

voltage: the measure of the amount of force that "pushes" an electric current.

watt: a unit of power (energy/time), the rate energy is consumed or converted to electricity.

Section V :

A "HOT" STATE

caldera: a bowl-shaped area, usually over 1 mile (1.6 km) in diameter, created either by a huge volcanic explosion (which destroys the top of a volcano) or by the collapse of a volcano's top.

lava flow: an area which has been covered by lava. ("Lava flow" may also refer to the rate at which lava runs out onto the earth's surface.)

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FOR THE TEACHER

CORRELATION OF GEOTHERMAL ENERGY CURRICULUM WITH 1990 CALIFORNIA SCIENCE FRAMEWORK – *Grades 4-8*

PHYSICAL SCIENCES

Section A: **Matter**

The following Framework sections correlate with Geothermal Energy Curriculum, pages 10, 13-15, 18-19, 23, 27, 42, 44:

A-1 Matter and its properties: Grades K - 3, 3 - 6, and 6 - 9
A-2 Basic units of matter, origin of matter: Grades 3 -6
A-3 Principles governing interactions of matter; chemical structure of matter: Grades 3 - 6

Section B: **Reactions and Interactions**

The following correlates with pages 9-10, 54-55:

B-1 Changes in substances: Grades K - 3 and 3 - 6
B-2 Controls of substances changing(e.g. environmental conditions, provision of energy, etc.): Grades K - 3 and 3 - 6

Section C: **Forces and Motion**

The following correlates with pages 8, 48-49, 51-57:

Introduction, Newton's Laws: Grades K - 9
C-2 Characteristics of forces and their relationship to motion: Grades 3 - 6 (forces between magnets, electrically charged objects can act without contact between the objects)

Section D: **Energy: Sources and Transformations**

The following correlates with pages 8-12, 36-44, 48-61:

D-1 Energy and its characteristics: Grades K - 3, 3 - 6, and 6 -9
D-2 How energy is used and changes that occur when using it: Grades K - 3, 3 - 6, and 6 - 9

Section E: **Energy: Heat**

The following correlates with pages 28, 36 -44, 53, 54-58, 70, 72- 76:

E-1 Heat energy, its origin and properties: Grades K -3, 3 - 6, and 6 - 9
E-2 How heat energy is used: Grades K - 3, 3 - 6, and 6 - 9

Section F: **Energy: Electricity and Magnetism**

The following correlates with pages 8, 11-12, 48-61, 72, 74, 76:

F-1 Description of electricity and magnetism, their properties and interactions: Grades K - 3, 3 - 6, and 6 - 9
F-2 Uses of electricity and magnetism: Grades K - 3, 3 - 6, and 6 - 9

EARTH SCIENCES

Section B: **Geology and Natural Resources**

The following correlates to pages 11, 18 - 29, 59, 71, 74, 76

Intro Plate tectonics - the unifying theory of geology today: Grades K - 9
B-1 Plate tectonics effect on earth's evolution: Grades K - 3, 3 - 6, and 6 - 9
B-2 Formation, distinguishing features and classification of rocks and minerals: Grades K - 3 and 3 - 6
B-3 History of the earth; how geomorphic processes have shaped earth's features: Grades K - 3, 3 - 6, and 6 - 9
B-4 Responsibilities of humans toward natural resources: Grades K - 3, 3 - 6, and 6 - 9

FOR THE TEACHER

CORRELATION OF GEOTHERMAL ENERGY CURRICULUM WITH 1990 CALIFORNIA SCIENCE FRAMEWORK – *Grades 4-8*

Continued

Section C: **Oceanography**

The following correlates to pages 20, 21, 22, 23, 24:

Intro Disciplines of geology, oceanography and meteorology are all interconnected; solar energy and forces within the earth are basis for the water cycle: Grades K - 9

C-1 The water cycle, how it affects climate, weather, life on earth, and surface features: Grades 3 - 6

C-2 What are the environments and topography of ocean bottoms: Grades 3 - 6 and 6 - 9

Explanatory Notes:

Only those sections of the 1990 Framework which directly apply to the concepts taught in the Geothermal Energy Curriculum have been identified in this correlation.

The topic of Geothermal Energy lends itself well to the thematic approach, as well as to interdisciplinary instruction. The exploration of this topic encompasses many big ideas, including deep time, plate tectonics, uniformitariaism, earth's cycles and their interactions, the electromagnetic force, forces and motion, and fundamental environmental principles.